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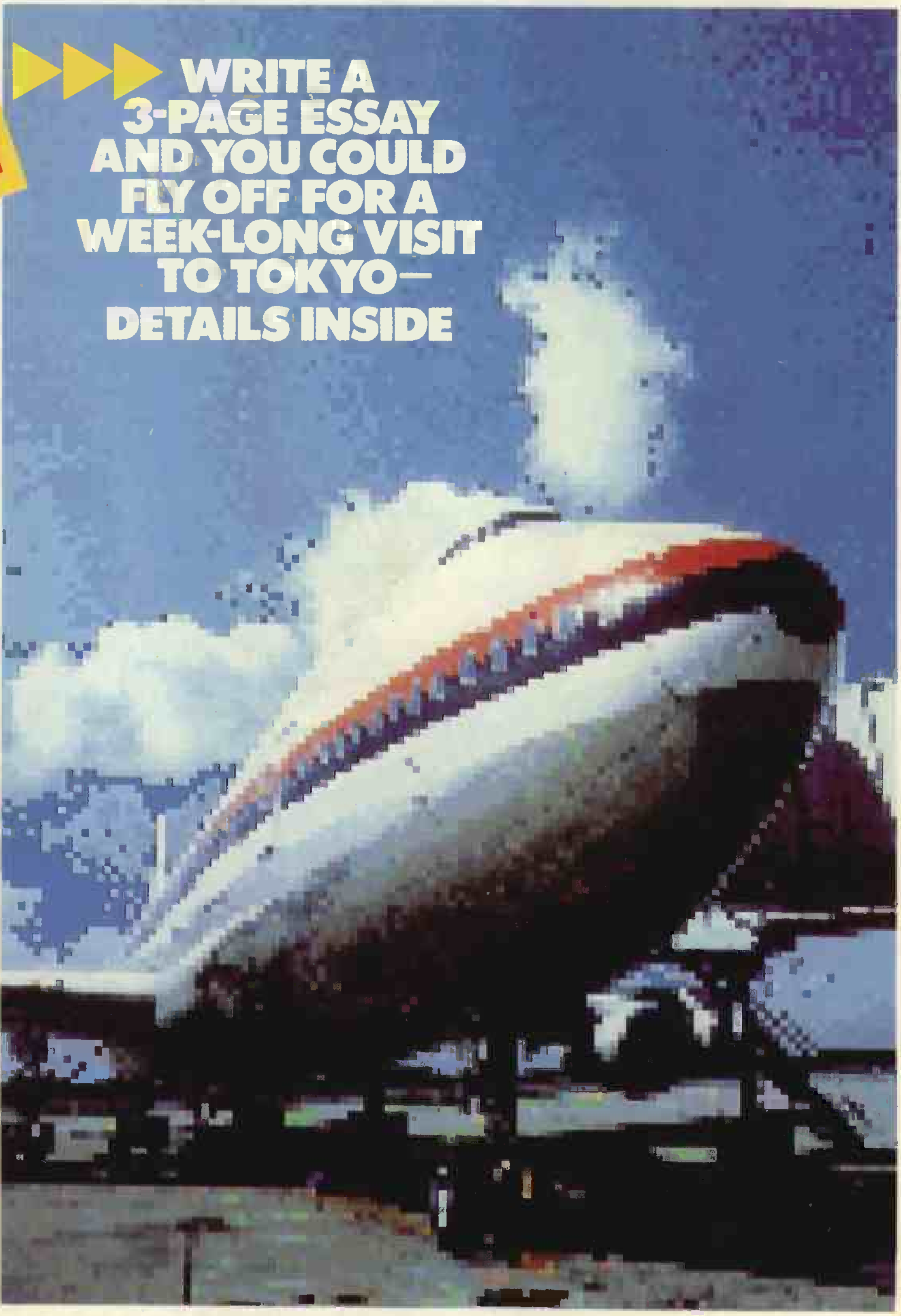

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COMMENT

Thoughts for the future

In the eighty-odd years since radio and the wider area of electronics began to develop, we have all been beneficiaries in one way or another. There is hardly any field of human activity which has not been affected, whether it is entertainment, communication, travel, medical research or industry in general.

All this is obviously greatly to be desired and the benefits of using electronics for these purposes cannot be gainsaid. But, nevertheless, one is sometimes conscious that there is, perhaps, an imbalance in the efforts applied to development. In recent years, the ingenuity of electronic engineers and capital investment have been directed to a constantly increasing extent to the development of space electronics, communications and 'defence' equipment which, if it achieves its aim, will never be used.

Communications apart, the majority of effort is wasted so far as direct benefit to mankind is concerned in the foreseeable future. In a world that is beset by deprivation of many kinds from the fundamental needs of life itself to the luxury of education, one could fairly hold the opinion that further developments in exotic electronics might at least be restrained in favour of a wider provision of more basic requirements.

The application of effort in our field of electronics might not seem immediately relevant to the alleviation of famine and pestilence but the attitude of mind that impels continuous investment of indulgent or lethal hardware is questionable. To expect companies throughout the world to turn down profitable development and production contracts would be naive, but a subsidized programme of development directed at more fundamental needs is perhaps possible.

Elsewhere in this issue appears the announcement of a competition in which readers are invited to set down their views on the way forward in engineering development. It may be that the admittedly idealized thoughts expressed above will be considered too ingenuous to be true, or that the existing regime is completely satisfactory. In any event, we expect to see a large number of thoughtful essays which should give rise to an interesting discussion, if nothing more useful than that.

Do, please, have a look at the announcement and let us have your thoughts – the prizes are very attractive and we are fortunate in that NEC, which has provided the main ones, is taking such a keen interest.

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The goniometer in electronic air navigation

From the early years of this century, the goniometer has played its part in direction finding and in Omnirange beacons. This article describes its working.

G.M.R. GRANT

As aircraft development made rapid advances in the opening decades of the present century, aids to more accurate navigation were continually appearing, although many of them would prove to be of marginal value. Indeed, by the middle of the 1920s, successful mail-carrying aircraft such as the De Havilland DH4M and the Curtis JN4H possessed only two really reliable navigational aids in the view of many of their pilots: the compass and the altimeter.

Attempts to utilize the evolving discipline of electronics for air navigation had already been made, one of the earliest examples of which was the Telefunken compass. Used extensively by the German Zeppelin crews in the course of World War I this equipment, in many aspects, indicated the way ahead. The ground transmitter fed a number of directional antennae, which could be switched sequentially and whose directional characteristics differed in orientation in 10 degree steps.

The major disadvantage of the equipment was that all the antennae had to have identical characteristics, by no means an easy manufacturing accomplishment at that time. Consequently, system balance was almost impossible to achieve, and when it was, it did not remain balanced for long.

Yet one of the oldest of electronic devices with directional properties had been patented as early as 1907, and was known by the names of its inventors: the Bellini-Tosi antenna system. As can be seen from Fig.1, it consisted of a pair of directional-loop antennae at right angles to each other, independently energized by a rotatable coupling device – a *goniometer*. This had similar characteristics to a large, rotatable-loop antenna, and produced fixed, equidistant courses in any desired direction, as opposed to particular lines dependent upon the position of the loops. Furthermore, it was simpler and more stable than the Telefunken compass.

By 1924, the earliest of radio beacons, the Homer or 'H Facility' had been commissioned for aeronautical use. This navigational aid is still with us, albeit in a more sophisticated form, and is known as the non-directional beacon, or n.d.b.

Two years later, the United States Congress passed the Air Commerce Act, in which the need for directional radio navigational facilities was first officially recognised in North America, and shortly after this initiative, the American Signal Corps developed an equi-signal beacon system, termed the

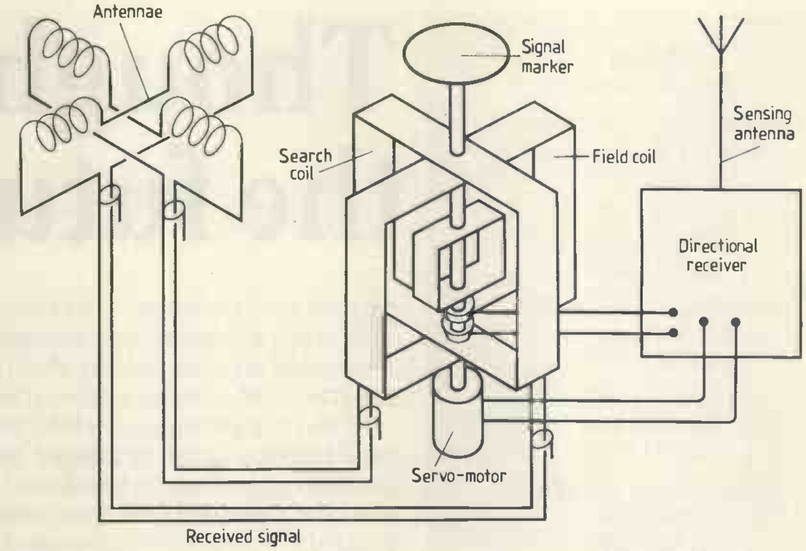


Fig.1. Two loops at right-angles are energized by the rotating coil on the axis – the goniometer – to provide fixed courses in any desired direction.

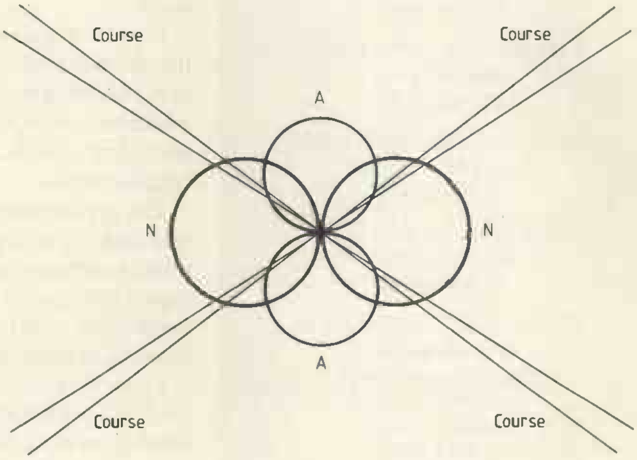


Fig.2. Field pattern of the four-course system, originated by the American Signal Corps.

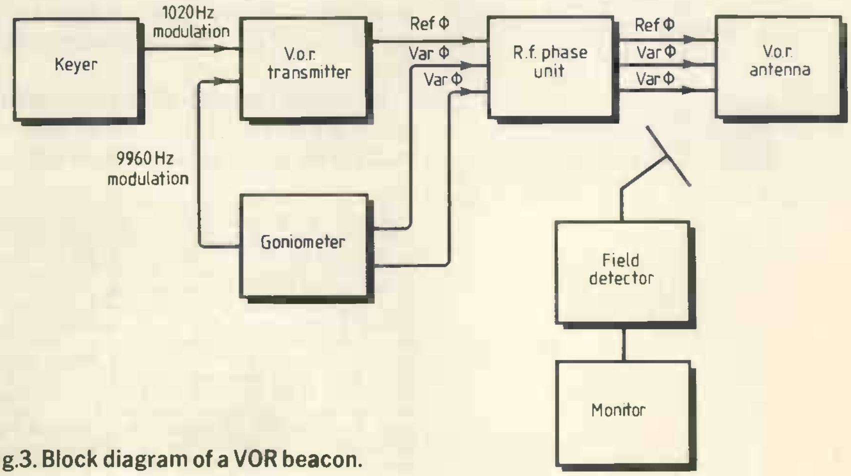


Fig.3. Block diagram of a VOR beacon.

radio range, or the four-course system.

This aid consisted of a tone-modulated transmitter working into two crossed, vertical-loop antennae, displaced by 90 degrees. The field pattern from each loop – as shown in Fig.2 – was a figure-of-eight, whose intersection produced four zones of equal field intensities or courses, roughly three degrees wide. In the beginning, course orientation was a considerable problem, but the incorporation of a number of technical improvements altered matters substantially. By far the most effective of these improvements was the installation of a goniometer between the transmitter and the loop antennae, allowing all four courses to be aligned in any direction. This improvement, together with the inherent simplicity of the basic system, explains why it was chosen for the first airway to be so equipped, that between New York and Cleveland, in 1927.

In the following year, London's Croydon airport "... had a radio-equipped control tower operating"[1], whilst across the Atlantic "odd and even altitudes for east and west bound aircraft were already established. Using the four-course l.f. range stations, inbounds flew the on-course centerline, outbounds flew well to the right of the centerline."[2]

In 1936, despite continuing problems with antennae and a phenomenon known as *night effect*, the four-course facility was adopted as the basic air navigation system in the continental United States.

The Bureau of Air Commerce meanwhile had drawn up a specification for a very high frequency aural range air navigation system, a specification that the Civil Aeronautics Administration – later to become the Federal Aviation Administration – had also endorsed.

The design and construction contract was won by the Washington Institute of Technology, who almost immediately began development on a v.h.f. system operating on a frequency of 125 MHz, an equipment whose core would be a further development of the original Bellini-Tosi patent; the goniometer.

GONIOMETER DEVELOPMENT

Rotating-capacitance goniometer. Consideration of Fig.3 indicates that, without the goniometer unit, the v.h.f. Omnirange (VOR) equipment is little more than a non-directional beacon. To understand why this is true, it is necessary to understand the theory behind the Omnirange concept.

Apart from the carrier, a VOR signal consists of two 30Hz modulation components, one of which is termed the *reference* signal, which is transmitted in a uniform manner in every direction around the VOR station. The other 30Hz component is called the *variable* signal, the result of what is termed space modulation, itself the result of the rotation of a directional radiation pattern at the VOR. This latter signal is identical in voltage and frequency terms to the reference signal, but its phase varies with azimuth, since it is generated by a rotating pattern.

Both these 30Hz signals are generated such that their instantaneous phases are co-incident along the line of magnetic North from each Omnirange station. Therefore, an aircraft at any point within range of the station is able to determine azimuthal position with respect to magnetic North merely by measuring the phase difference between the reference and the variable signals, both of which are generated by the goniometer, whose function is to convert carrier energy into sideband energy. The goniometer in short, is a form of transducer.

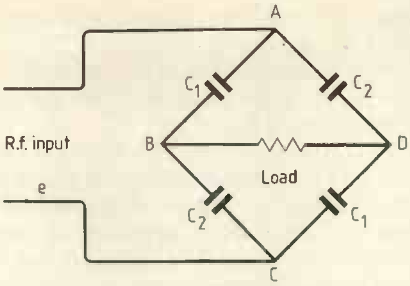


Fig.4. The rotating-capacitor goniometer as a capacitance bridge.

Obviously, it is vitally important that both the reference and the variable signals – which are at the same frequency – retain their identities whilst being transmitted and received on the same carrier. This is achieved by using the 30Hz reference signal to frequency-modulate a 9960Hz sub-carrier at a deviation of ±480Hz, and then using this composite signal to amplitude-modulate the main r.f. carrier, which will be within the range 108 to 118MHz. In their original design submission, the Washington Institute of Technology specified a rotating-capacitance goniometer.

This device would – in their judgement – be practical, stable and accurate, particularly at v.h.f. It consisted of two rotating capacitive couplers with the rotors mounted on a common shaft. The stators had a physical orientation of 90 degrees to each other, and the motor shaft was driven by a 30 r.p.s synchronous motor which, when fed with pure sinusoid, gave goniometer outputs of

$$e_1=E_m[\sin(\omega+p)t+\sin(\omega-p)t]$$

and

$$e_2=E_m[\cos(\omega+p)t-\cos(\omega-p)t]$$

where E_m=maximum amplitude of the applied r.f. voltage
$\omega=2\pi \times$ the carrier frequency
$p=2\pi \times$ the goniometer rotation in Hz.

Output voltage 1 would therefore be at zero when output voltage 2 was at maximum. The arrangement was as much mechanical as it was electrical, for both the rotor and stator plates were accurately shaped in the course of manufacture to ensure that, as output 1 increased to maximum as a sine function, output 2 decreased to zero as a cosine function. In other words, the resultant sideband phasors were in phase coincidence, and their resultant amplitudes varied in quadrature with respect to time.

Fig.5. Signals 90° out of phase, together with differentially varying amplitudes, provides a rotating pattern.

In mathematical terms, for output 1

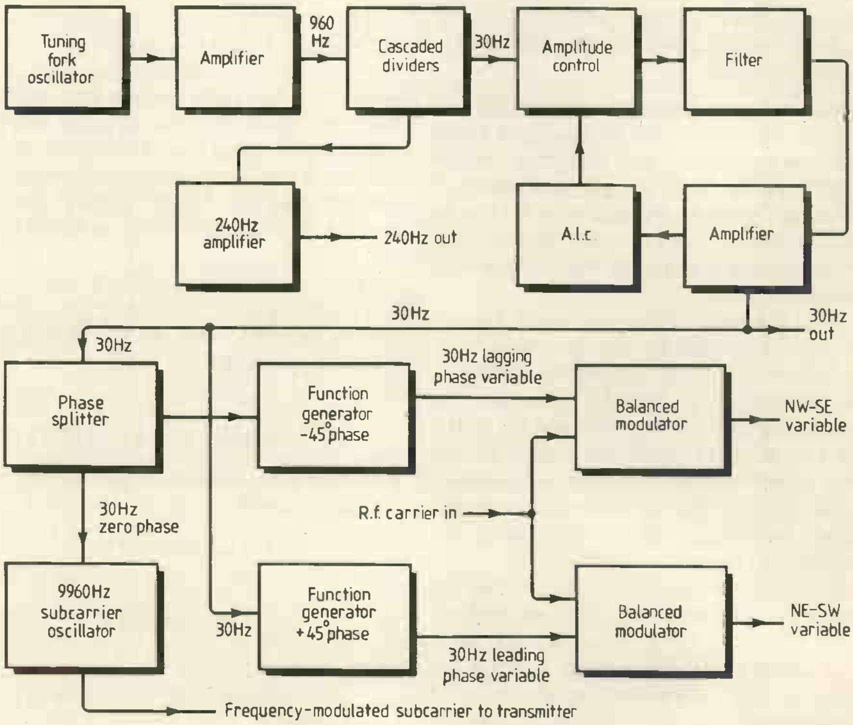
$$C_1=k(1-\cos pt) \text{ and } C_2=k(1+\cos pt) \quad (1)$$

and for output 2

$$C_1=k(1-\sin pt) \text{ and } C_2=k(1+\sin pt) \quad (2)$$

where k=a constant, dependent upon the maximum capacitance achieved between the plates
t=the instantaneous angular position of the rotor.

This can best be understood by regarding the goniometer as a capacitor-bridge, as shown in Fig.4. The input voltage $e = E_m \sin \omega t$ will divide such that the voltage between points



B and C will be

$$e_2=e\left(\frac{1/C_2}{1/C_1+1/C_2}\right)\text{or } e\left(\frac{C_1}{C_1+C_2}\right)$$

and that between points D and C will be

$$e_1=e\left(\frac{1/C_1}{1/C_1+1/C_2}\right)\text{or } e\left(\frac{C_2}{C_1+C_2}\right)$$

The load voltage, therefore, between B and D will be

$$E_z=e_2-e_1=e\left(\frac{C_1-C_2}{C_1+C_2}\right)$$

Substituting values for C_1 and C_2 from Eqs (1) and (2):

$$E_{z1}=\left[\frac{(1-\cos pt)-(1+\cos pt)}{(1-\cos pt)+(1+\cos pt)}\right]$$

$$= E_m \sin\omega t\,(-\cos pt).$$
$$= -E_m[\tfrac{1}{2}\sin(\omega+p)t + \tfrac{1}{2}\sin(\omega-p)t]$$

$$=\frac{-E_m}{2}\sin(\omega-p)t - \frac{E_m}{2}\sin(\omega+p)t \quad (3)$$

We can regard the second section of the goniometer in the same manner, and the output voltage across the load – since the stator is displaced 90 degrees from the other section – will be

$$e_{z2}= e\left[\frac{(1+\sin pt)-(1-\sin pt)}{1+\sin pt)+(1-\sin pt)}\right]$$

$$= E_m \sin\omega t \sin pt.$$

$$=\frac{E_m}{2}\cos(\omega-p)t - \frac{E_m}{2}\cos(\omega+p)t \quad (4)$$

Equations (3) and (4) therefore show that only sideband frequencies of

$$\frac{(\omega+p)}{2\pi}\text{ and }\frac{(\omega-p)}{2\pi}$$

are present at the output terminals, and that the voltages present are in phase quadrature, thus satisfying the requirement for supplying sideband voltages with variations of $E_m\cos pt$ and $E_m\sin pt$ at the goniometer output terminals.

Electronic goniometer. The goniometer was entirely responsible for the quality of a VOR antenna's patterns, and therefore for the quality of the VOR bearing indications. A rotating-capacitance goniometer had to be an accurately manufactured device, with both its input and output circuits balanced to earth.

This last was not always achieved, however, and mechanical goniometers occasionally demonstrated input impedance variations in the course of rotation, thus causing amplitude and/or phase modulation of the r.f. energy at the input. The reason for this was sometimes an inaccurately manufactured goniometer, or an incorrect impedance termination of one or both of the goniometer outputs.

Design engineers began to consider an electronic goniometer, one that retained the properties of both the electro-mechanical type and the original, namely "... that the direction of maximum radiation or of greatest response may be rotated in azimuth without physically moving the antenna array."[3]. Figure 5 demonstrates one way in which the above condition was met. The vital components of the design are the function generators, which create two 30Hz signals, phase-displaced 90 degrees.

To create a figure-of-eight radiation pattern, an r.f. source must drive the antennas with separate c.w. signals, displaced by 90 degrees. The pattern produced by this arrangement, however, is stationary and so must be made to rotate.

This is achieved by arranging that the goniometer modulates both the c.w. signals. In so doing, the goniometer varies the amplitude of the crossed-antennae patterns, and so the resultant voltage maximum also varies. Therefore, if the signal amplitude to one dipole or slot antenna is increased, and that to the other decreased, the radiating figure-of-eight will change in direction, clockwise.

The radiating figure-of-eight, therefore, can be made to assume any direction, simply by a choice of amplitude ratio between the two driving signals. Moreover, if the amplitude ratio is changed at a sinusoidal rate, the change in directivity will be constant, and the frequency of the amplitude change will be directly proportional to the rotational speed.

The variable pattern must rotate at 30 r.p.s. to produce 30Hz space modulation of the reference carrier. The balanced modulators in Fig.5, consisting of varactor bridges, modulate the carrier with both the 30Hz signals from the function generators, to create signal rotation.

Figure 6 shows the mechanism. During a time-interval of 1/60th of a second, one antenna pair will receive a single pulse, whose amplitude varies sinusoidally from zero to maximum, and then returns to zero. The second antenna pair will receive the same signal, but phase-displaced by 90 degrees. In the course of this opening time-interval, the radiated figure-of-eight pattern will have rotated through 180 degrees. During the next 1/60th of a second period, both antenna pairs receive the same signal as before, but the pulse polarity has reversed, with the result that the radiated antenna pattern has rotated from 180 degrees to 360 degrees. It is the goniometer that creates the rotating pattern, through feeding the stationary antenna pairs with modulated signals.

Obviously in such a situation, a constant-amplitude signal would negate the object of the modulators, and so the goniometer carrier is suppressed.

ANTENNAE DEVELOPMENT

FAA four-loop antenna. A goniometer produces two signals:

$$V_1 = e_m \sin\omega t \cos\Omega t$$

and

$$V_2 = e_m \cos\omega t \cos\Omega t$$

where m = modulation depth.
ω = angular frequency of modulation (30Hz).
Ω = angular frequency of the carrier.

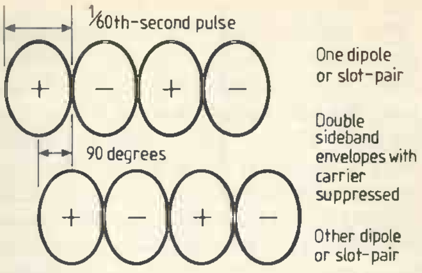


Fig.6. The system of Fig.5 produces this effect at the antennae.

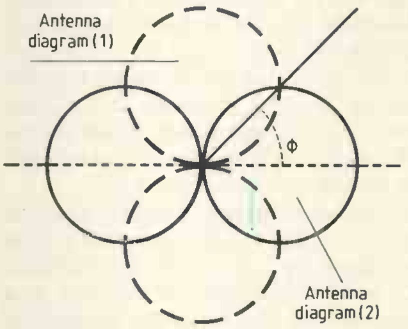


Fig.7. A four-loop antenna, when fed with phase-shifted signals, gives the resultant of the two in space.

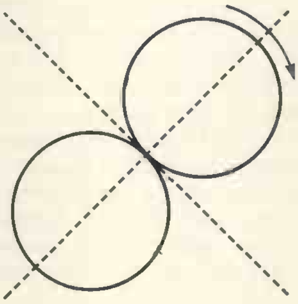


Fig.8. The rotating figure-of-eight given by the antenna pattern of Fig.7.

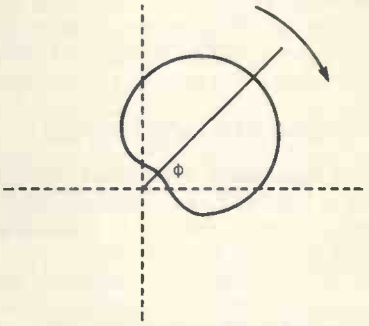


Fig.9. Adding the carrier of the omni signal provides a cardioid pattern.

In Fig.7, if one antenna is fed with signal v_1, and the other with v_2, the resultant in space will be the sum of the two electromagnetic fields.

$$e_1 + e_2 = E_m\sin\omega t\cos\Omega t\sin\phi + E_m\cos\omega t\cos\Omega t\cos\phi$$
$$=E_m\cos\Omega t(\sin\omega t\sin\phi, + \cos\omega t\cos\phi$$
$$= E_m\cos\Omega t\cos(\omega t-\phi)$$

This sum represents a rotating figure-of-eight, as shown in Fig.8.

When the carrier of the omnidirectional signal is added, in space, the resultant is

$e_{(total)} = E\cos\Omega t + E_m\cos\Omega t\cos(\omega t-\phi)$ where $E\cos\Omega t$ is the reference signal, and $E_m\cos\Omega t\cos(\omega t-\phi)$ is the variable signal, or

$$e_{(total)} = E\cos\Omega t[1+m\cos(\omega t-\phi)]$$

This equation represents a cardioid which rotates – at 30 times per second – a signal modulated with 30Hz, being emitted at an angle ϕ, as shown in Fig.9.

An Omnirange antenna, therefore, must be capable of radiating a reference signal and a variable signal of similar frequency, yet with the relative phase being related to azimuth.

In the early days of VOR development, the azimuth signal was transmitted by a rotating dipole, a method that was soon discarded, for two main reasons: the first mechanical and the second electronic. The rotational speed of 1,800 r.p.m. brought about excessive centrifugal force, frequently subjecting the antenna drive motor to bearing failure. This meant the replacement of the motor, which also entailed the shutdown of the VOR station, and hence a gap in aerial navigational coverage.

Electronically, such a considerable rotational speed did not produce pure horizontal polarization, which had been early established as a prime requirement for the success of v.h.f.-based electronic navigation equipment.

Between 1950 and 1958 however, several new Omnirange antennae were developed, among which were the Federal Aviation Administration's Four-Loop antenna; the Collins Slotted Cylinder antenna, and the Alford Slot antenna unit. Figure 10 shows the FAA's four-loop system.

As can be seen, the orientation of the loops is respectively northwest, northeast, southwest and southeast. They are fixed to an antenna support plate, itself supported in position by four hollow-metal pipes, some four feet above the artificial ground plane, a 52-foot diameter metal counterpoise. The antennae feeder cables pass through the hollow support pipes. Provided a loop is situated such that it is clear of other metal objects and obstructions, it will radiate a horizontally polarized, circular pattern.

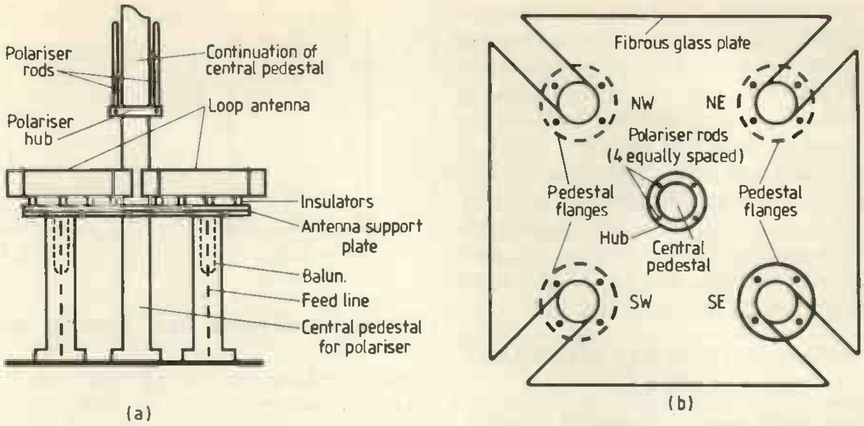


Fig.10. The FAA four-loop antenna. At (b) is the plan of the antenna layout and the feed to the polarizer rods.

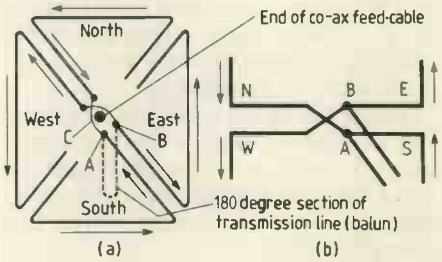


Fig.11. Method of feeding antennas in the system of Fig.10.

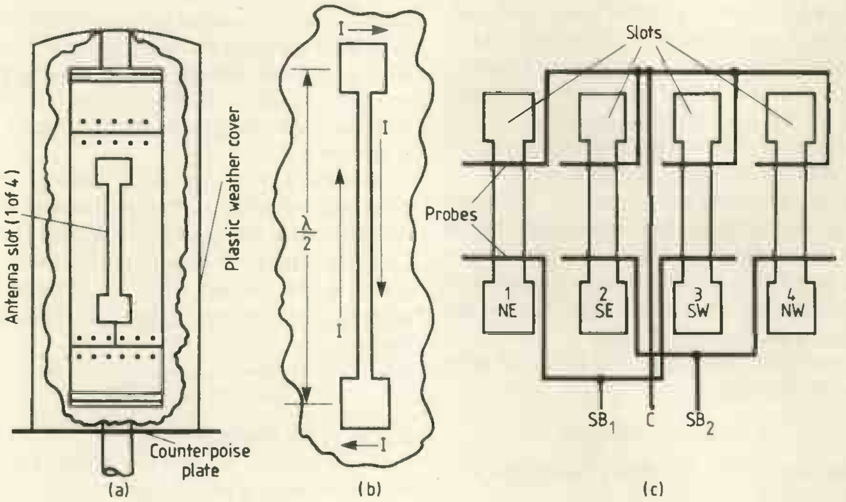


Fig.12. Alford slot antenna, with antenna feeds.

Each loop was fed to points A and B in Fig.11 and the balance-to-unbalance transformer section between them. The current flow in the sides of the loop is that indicated in Fig.11(a) for a given instant of time.

Current entering at point B would flow outwards to the west and east sides, whilst current entering at point A would flow inwards from north and south respectively. In other words, while current flow inevitably alternates, it is always in the same direction in all four arms, at any instant. This directional current flow or, in other words, antenna polarity, could be altered by simply reversing the polarity of the balun transformation section at A and B.

When all four loops were installed, the jumpers were connected such that the NW-SE sections and the NE-SW ones had opposite polarity, so as to ensure the generation of two separate figure-of-eight patterns.

The $e_{(total)}$ equation shows that the relative phase of the 30Hz signal bears a direct relationship to ϕ, the azimuth. When $\phi=0$, maximum signal strength is received when ωt is also zero. This is because the cosine function is maximum when the angle $(\phi-\omega t)$ is zero. For other azimuths, if $\phi = 0$ is set up at north, the maximum of the 30Hz is delayed in phase by an amount equal to the azimuth. In other words, at azimuth 90 degrees ($\phi=90$) maximum signal strength is received when ωt is 90, in order to again make $\cos(\phi-\omega t) = \cos 0 = 1$.

If computations are carried out for all azimuthal positions, the instantaneous phase of the 30Hz component will be seen to lag the instantaneous phase of the voltage at 0 degrees azimuth by an amount equal to the azimuthal position of the aircraft. This condition is the same as a cardioid pattern rotating at $\omega/2\pi$ Hz.

Alford slot antenna. Perhaps the best known antenna for Omnirange operation is the axial slot. This is far from surprising for "... the circular cylinder is the simplest geometry involving a curved surface"[4] as Compton and Collin have observed, and one of the antennae designed around this precept is the Alford slot. Figure 12 illustrates the physical and electrical properties of this type of antenna.

A simple metal cylinder containing four axial slots evenly spaced around its circumference, the Alford slot, or slightly modified versions of it, has been used by a number of manufacturers in Omnirange equipment design. The four slots are energized with both carrier and sideband power in a similar manner to that utilized in the FAA loop. In Fig. 12(c), carrier energy is fed to the four slots at point C, each of them being excited in phase coincidence by probes at the end of their 200Ω, 1/4-wavelength, open-wire transmission lines.

Figure 12 (b) shows how this antenna functions. Each individual slot is electrically about half a wavelength in length, and physically rather narrow. Moreover, it is energized such that the current flow around it is that illustrated. Consequently, the vertical component of the radiated energy is suppressed, as the currents flowing on either side are in phase opposition, hence cancelling each other out. The currents flowing across the ends of the slot produce the horizontally polarized radiation, which is suppressed only at the vertical angle of 0 degrees. Thus the horizontal space field-intensity varies with the vertical angle in the same manner as does that from two horizontally polarized antennae placed one above the other, with a 180 degree spacing.

GONIOMETER AND ANTENNAE ERRORS

As has already been demonstrated, the quality of the bearing information transmitted by a VOR station is dependent almost entirely on the variable signal source and on the radiating elements; in other words on the goniometer *and* the antennae.

If, as in Fig.13, two horizontal-loop antennae are spaced S degrees apart, and energized with equal but oppositely phased voltages, the field intensity around the array will vary with the position of the field strength monitor.

Figure 13(a) shows two loop antennae A and B, spaced S degrees apart. Point P is assumed to be at least 25 feet from the VOR antennae. Therefore lines drawn from both the antennae and point P can be taken to be parallel. The field intensity at point P is zero, since it is equidistant from both antennae, and so the field intensities cancel. At this position of P, line d is perpendicular to a line through the antennae, and so da = db.

As the receiving point is moved clockwise, there is a change in the relative lengths of da and db, as shown in Fig.13 (b). This causes the signals from A and B to be delayed and advanced respectively, changes that are depicted as phasors in Fig.13(c).

From this latter diagram, it can be seen that the resultant

$$E_{ab}=E_a\sin\mu+E_b\sin\mu$$

and since $E_a=E_b$, the above expression can be written as

$$E_{ab}=2E_m\sin\mu \qquad (5)$$

where E_m is the maximum intensity from the combined antennae. Figure 13 (b), on the other hand, shows that $\mu=S/2\sin\Omega$, and if this expression is substituted in Eq(5), the result is

$$E_{ab}=2E_m\sin(S/2\sin\Omega) \qquad (6)$$

When values of both Ω and spacing symbol S are inserted in (6), the typical figure-of-eight pattern values are determined. In such a case, S/2 is nominally 56 degrees. Thus the "flattening" due to finite spacing can be established by comparing this pattern with one plotted from the same equation when S approaches zero.

When the latter happens, i.e. $S\rightarrow0$, $E = 2E_m\sin\Omega$. With the addition of a second pair of antennae C and D, at 90 degrees to A and B in Fig.13, the field intensity pattern equation for this additional pair, based on the same azimuth angle Ω, becomes $E_{cd}=2E_m\sin(S/2\cos\Omega)$. This is shown in Fig.14.

Hitherto, we have regarded the antennae under consideration as being ideal, with the radiation pattern for any pair behaving in accordance with the equation $E = E_m\sin\Omega$. This results in a radiation pattern in the form of two perfect circles, and whilst such idealized conditions do not exist in practice, current techniques can come considerably close to such an ideal. Nevertheless, as S approaches Ω, the magnitude of the field intensity approaches Ω also. Therefore a complete cancellation of energy occurs when two antennae – energized by currents of equal magnitude but opposite polarity – occupy the same point. Obviously therefore, S must have a finite value.

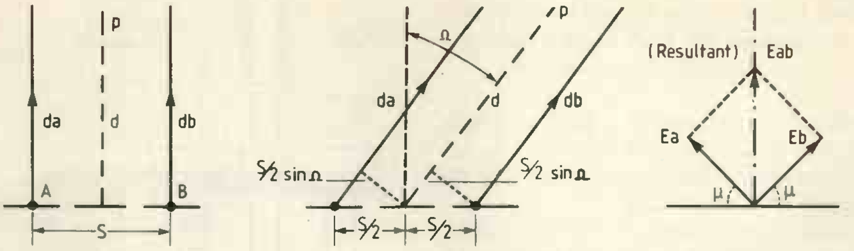


Fig.13. Variation of field intensity with position relative to antennae.

Figure 15 illustrates the radiation pattern of a pair of practically spaced antennae compared with the ideal figure-of-eight. The solid lines show the shape of the curve based on the practical spacing of S = 112 degrees and the equation $E_m\sin(56\sin\Omega)$. The bulging or geoidal appearance increases as S is increased.

The space field intensity cannot vary strictly as a sine function when the pattern is rotated if the figure-of-eight is imperfect. Consequently, bearing information reaching the aircraft from the "practical" antenna contains errors that vary with azimuth.

ERROR CURVES

Figure 16 is a bearing error curve, which was calculated on the basis of the standard VOR antennae spacing of 112 degrees. The calculated error illustrated is theoretical, showing eight points of maximum error in 360 degrees. Consequently, the error produced by antennae spacing is known as *octantal* error.

In Fig. 17 the positive and negative designations indicate the relative r.f. phases, the circles being ideal, undistorted by finite spacing considerations. The goniometer setting is 45 degrees, and so the r.f. energy is divided equally between the two pairs of antennae and, consequently, will be 0.707 of its maximum value.

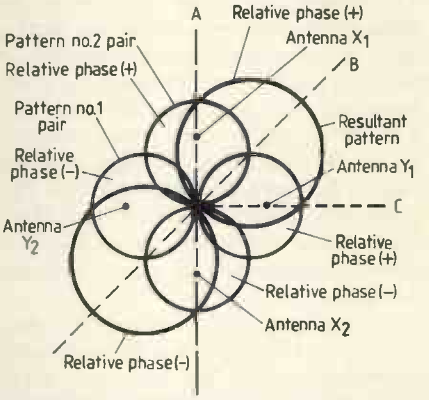


Fig.14. The effect of adding a further pair of antennae at right-angles to those in Fig.13.

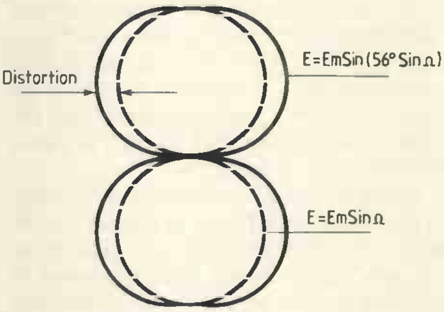


Fig.15. In a practical antenna system, the spacing produces a distorted figure-of-eight.

Since the circles represent r.f. voltage patterns of carrier frequency, they can simply be added algebraically. It can be seen therefore that the positive 1 and 2 circles will add, giving a maximum in the North-East direction, whilst negative circles 1 and 2 will provide a correspondingly negative maximum in the South-West direction.

We have, therefore, the resultant pattern for this position of the goniometer, extending North-East to South-West, with a null perpendicular to this direction. The angular position of the goniometer must always

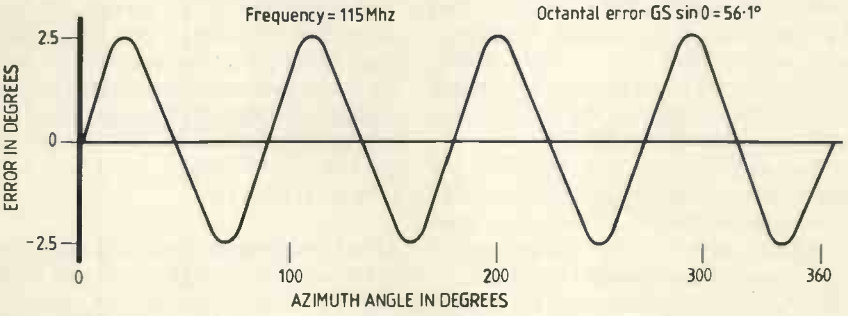


Fig.16. Bearing error curve for a spacing of 112°.

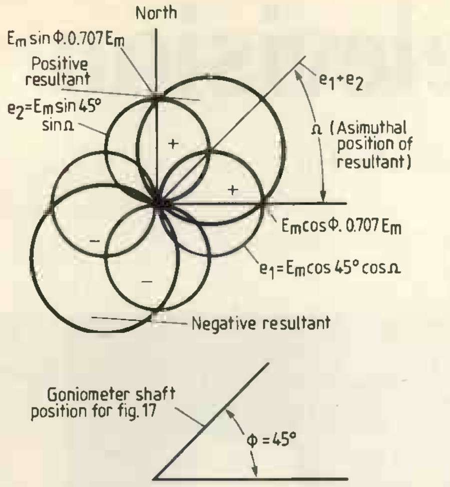


Fig.17. Mechanism producing figure-of-eight pattern at 45° for that position of the goniometer.

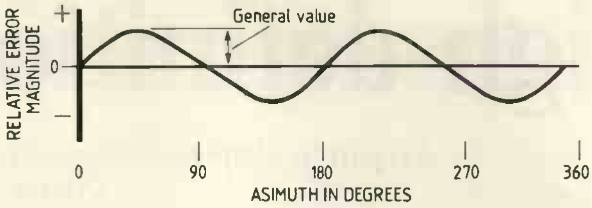


Fig.19 Quadrantal error caused by imbalance between antennae.

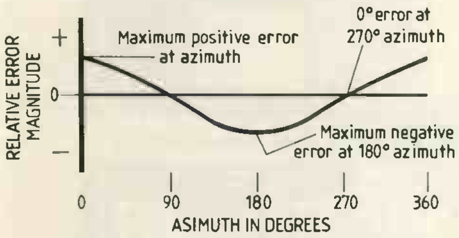


Fig.18. Duantal error caused by phasing discrepancy.

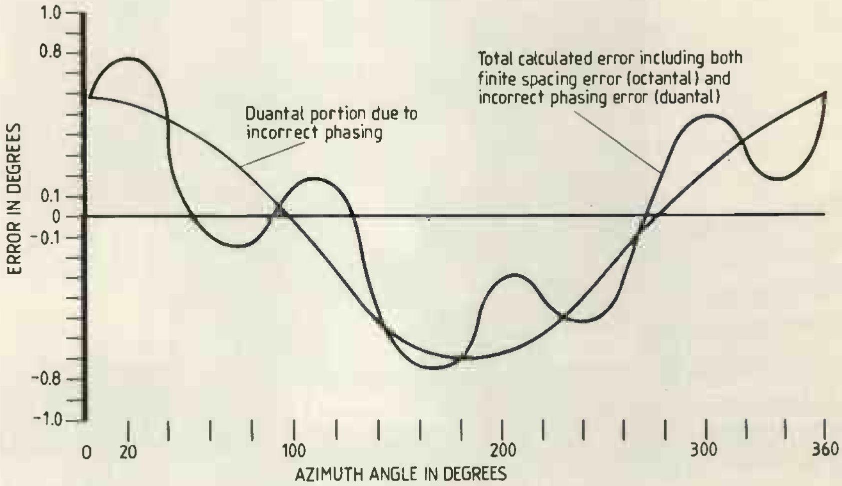


Fig.20. Composite error curve produced by misphasing and the effect of spacing of antennae.

agree with the exact azimuthal alignment of the resultant figure-of-eight, if azimuthal error is to be avoided. The resultant has been plotted as a function of e_1 and e_2, whose combined value is a constant, $E_1 = 0$. Each is 0.5 because the size of the positive circle has been reduced from its nominal value to 0.707, as the goniometer has traversed through 45°.

The phase angle of the modulated wave arriving at the aircraft receiver is $B = \tan^{-1} \sin\Omega/\cos\Omega$ where the antenna spacing S approaches zero, or

$$B = \tan^{-1}\sin(S/2\sin\Omega)/\sin(S/2\cos\Omega) \qquad (7)$$

where, as before, Ω is the azimuth or, definitively, the angular position in space of the receiver; and S/2 is 56 degrees for the standard VOR.

Substituting values from 0° to 360° in Eq(7), gives the calculated values of B that equal the assumed values of Ω at the cardinal and semi-cardinal positions i.e. at $\Omega = 0°$, 45°, 90°, 135° etc., whilst at the intermediate angles, the difference between Ω and B varies sinusoidally, the maximum difference being 2.5° at eight places, as shown in Fig.16.

There are a number of causes of Omnirange error; among the major ones, the following are the most important. Whenever there is a phasing discrepancy, the error between the position of the resultant figure-of-eight and the goniometer position varies with the point of measurement around the VOR station. Figure 18 is a graph showing the shape of the error curve, and since there are two azimuthal positions of maximum discrepancy, the error caused by misphasing of an antenna is called *Duantal* error.

Power imbalance between antennae is another cause of error. When there is unequal excitation of both pairs of slots or loops, the basic figures-of-eight are of unequal size, a discrepancy which results in a variation of the position of the resultant rotating figure-of-eight **Ω**, with respect to the goniometer's angular position φ. Assuming that the maximum radiation given out by one pair of antennae is E_{ma}, and that of the other pair is E_{mb}, then the position of the rotating pattern $\phi = \tan^{-1} E_{ma}\sin\Omega/E_{mb}\cos\Omega$

$$\text{or } \phi = \tan^{-1} E_{ma}/E_{mb}\tan\Omega. \qquad (8)$$

Substituting values of Ω in Eq(8) gives an error curve having four peaks of discrepancy, as shown in Fig.19. This is termed a *Quadrantal* error curve. Finally, Fig. 20 illustrates a calculated error curve, which was produced for a misphasing error of 10 degrees between one antennae pair. The octantal scalloping superimposed on the duantal phasing error is the result of the finite spacing of 61 degrees between the antennae.

PRESENT STATE OF THE ART

Currently, the most advanced Omnirange system is the Doppler VOR or DVOR as it is frequently termed. The principle behind this system was first enunciated by the Austrian mathematician and physicist Christian Johann Doppler, who died about a year before the opening of the Great Exhibition of 1851. The Doppler effect is the "...apparent change in the frequency or radio wave reaching an observer, due either to motion of the source towards or away from the observer, to motion of the observer, or both."[4]

In equipment terms, the antennae array consists of a counterpoise some 30 metres in diameter, in the centre of which the carrier antenna is located. Arranged around it are a ring of 50 sideband antennae, the azimuthal information being commutated around this ring, in a manner similar to the earlier commutated-antenna direction-finding system.

Such equipment "...has considerably improved the VOR system performance since such beacons have much greater immunity from multi-path propagation effects."[5] Perhaps the most revealing indication of the progress in electronic air navigation over the last 40 years however, is the fact that the i.f. Four-Course system has become the first electronic navigational device to be phased out of operation, and indeed existence. Moreover, the very success of its latter-day equivalents have had an equal effect on aircraft crew complement.

The civil airliners of almost all nations have long ceased to carry either a navigator or a radio operator. Both may be considered the earliest human casualties of the success of electronic air navigation in general, and of the goniometer and its derivatives in particular.

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High-definition television

A report from the recent international colloquium held in Ottawa

GEOFF LEWIS

This suite of high-definition production equipment by Sony is based on the Japanese 1125/60 format adopted by NHK.

It may be recalled that the CCIR meeting in Dubrovnik in May 1986 was very much concerned with the establishment of the NHK/Muse h.d.tv system as a world-wide production standard and possibly as a transmission standard as well. It was stated at the time that, if no decision was reached, then Muse might well become a *de facto* standard. What started out as just an evolutionary/revolutionary argument between the Muse and the European MAC proponents expanded into a 50Hz versus 60Hz disagreement. These deliberations ensured that no decision would be achieved before the 1988 or even 1990 meetings. The European team returned to their Eureka '95 project that is sponsored by the European Community and managed by the European Broadcasting Union (EBU) to continue the search for a standard based on the MAC system.

Europe's challenger, E-MAC (Independent Broadcasting Authority).

From the papers presented and the comments made in Ottawa, it appears that it was not only the European camp that went back to the drawing board: the North America research establishments also appear to have an enthusiasm for evolution. A significant number of technical papers and demonstrations presented various ways of introducing h.d.tv or Extended-Definition Television (e.d.tv) into the market place, via improved systems that were NTSC-compatible. A commonly occurring comment was that h.d.tv was only likely to be commercially acceptable if it was introduced into an already installed customer base. Research in the USA has shown that, apart from the FLYERS and TINKs groups (Fun Loving Youth En Route to Success and Two Incomes, No Kids), the public was loath to spend more than about $500 on upgrading its television or audio systems.

The question of whether h.d.tv is wanted was easily answered. Current display technology is now about 30 years more advanced than systems originally designed to convey the images; imperfections are now clear for all to see. But the question of how to introduce h.d.tv and avoid considering compatibility was more difficult. Any h.d.tv signal received and processed via a converter and remodulated for display on a current receiver is bound to be shown at a disadvantage. Unless h.d.tv programmes have a sufficiently high viewer appeal, this approach is unlikely to enhance the sales of true h.d.tv receivers. Generally, the compatibility concept was seen as a deterrent in the development of a single world standard. Even in the production areas, NTSC's field rate of 59.94Hz and film with a 24/25 frames per second rate was problem enough without adding the MAC/Muse, 50/60Hz incompatibilities. One proposal was for the evolution of separate 50Hz and 60Hz standards to service their respective areas of the world and then to devise a single world-standard conversion system.

The next obvious question was whether such an innovation concept as h.d.tv warranted compatibility, or whether a completely new system, unfettered by compatibility, might not be a better approach. This, of course, offers an easy solution, but would be a certain financial failure.

A major problem in standards conversion that still has to be resolved is that of adaptive motion interpolation, particularly at low cost for installation in a receiver. A high-cost unit may be acceptable in the rebroadcast environment, but this does really solve a problem that is basically one of bandwidth compression. A major part of the problem lies in the large amount of frame store needed, plus digital processing. Compensation for a single movement within an image is fairly easy to achieve, but significant problems still exist when two or more movements occur simultaneously within an image. This is just one area of h.d.tv that is receiving considerable attention in the research laboratories around the world.

Papers presented by psychologists and others involved in the area of subjective perception and image evaluation called into question the current methods of assessing picture quality. These referred specifically to the double-stimulus method, whereby test viewers are shown a degraded picture alongside a standard reference one and asked to assess the degradation against a standard quality scale. The problems arise when trying to assess high-grade images. Recent testing has shown that certain effects, such as a peaky response, tending to sharpen vertical image edges, can produce a higher score than the reference image. Tests have also shown a context sensitivity, where images such as sporting scenes with a great deal of movement, or those that concentrate the interest into a small area, can give rise to a higher rating than other equally degraded pictures.

The delivery of h.d.tv signals via d.b.s. satellites also involves financial considerations. It was announced that Japan intends to start its d.b.s. service, using the NHK/Muse system, in 1990. However, the intention is to introduce this alongside an enhanced NTSC system to build on the current receiver base. Like Europe, Japan intends to start this service in the Ku-Band. In North America, it was thought likely that d.b.s. transmissions would use C-Band (in spite of the problems of terrestrial interference that have been experienced in the past), because there was an already significant C-Band customer base using the fixed satellite services.

DEMONSTRATIONS

Many of the demonstrations were based on the NHK/Muse encoded signals with parameters of 1125 lines per frame, 60 fields per second and 2:1 interlace. Base bandwidth for luminance and chrominance are 30MHz and 2×15MHz respectively; a total bandwidth of 60MHz. In the Muse system, the composite signals are bandwidth compressed, using a complex digital process to achieve final values of 16.2MHz for Muse-T and 8.1MHz for Muse-E. The Muse-T variant is intended for the transmission of higher quality signals that are ultimately intended for rebroadcasting or networking. Over a satellite link, Muse-T uses frequency modulation and requires a full transponder bandwidth of 54MHz. The Muse-E version is intended for direct reception and can be accommodated in 27MHz of r.f. bandwidth.

> **'Because of the high costs involved, any . . . accepted system will have to stand the test of time, perhaps the next 30 to 40 years.'**

Telesat Canada's Anik-C2 satellite was used for the demonstrations, positioned at 110° west and using Ku-band transponders, which provided a down link e.i.r.p. of 49.5dBW. Three antennas were in use at different times, the largest at 4.5 metres diameter providing Muse-E signals with a C/N ratio of 24dB in a 27MHz bandwidth. The Muse-T signals with double the bandwidth thus carried a 3dB penalty, but this was not obvious under normal conditions.

CHASING RAINBOWS

Without doubt, the most prestigious demonstration was the hour-long transmission, via satellite, from the Canadian Broadcasting Corporation's (CBC) production set in Toronto. A wide range of excerpts from the new production *Chasing Rainbows* was being shown. This 14-hour-long drama serial is the world's first to be produced entirely using h.d.tv equipment and techniques. The transmission system used was Muse T and the display presented on a 16ft×9ft projection screen. It was interesting to note the different approaches to the assessment of picture quality: whilst engineers peered closely to examine any graininess, artistic individuals stood back to appreciate the total aesthetic impression. This impressive demonstration ended with a video/teleconferencing session between the producer, director and executive engineer in Toronto and delegates with questions in Ottawa. *Chasing Rainbows* was said to have been produced on a 16mm film budget, with h.d.tv being used as an act of faith after seeing earlier demonstrations. Various reasons were quoted for not using film: as 35mm film is considered to have a resolution of about 1000 lines, h.d.tv should produce better quality images than 16mm film. Additionally, h.d.tv was thought to be more flexible than film in the production environment. No costs for the h.d.tv equipment, which was supplied by Sony of Canada Ltd, were quoted except to state that it was provided at a promotional rate.

CABLE TELEVISION DEMONSTRATION

The robustness and flexibility of the Muse-E signal was demonstrated by the use of cable distribution, the signal being transmitted from Ottawa Congress Centre, via the Anik satellite in Ku-band, to the cable head end of Skyline Cablevision Ltd, about 6km cable distance away. Here, the signal was down-converted without demodulation to 425MHz. The 27MHz bandwidth signal was then transmitted over the cable system alongside the normal cable service. This cable system is capable of supporting up to 60 standard NTSC channels, so the fact that Muse occupied rather more than four channels was no embarrassment. At the Congress Centre, the cable signal was up-converted to 1GHz and input to a standard Muse receiver. Even by cable standards, the display was of a very high quality. Skyline Cablevision has around 105 000 customers, cable penetration being as high as 80% in Canada.

OPTICAL VIDEO DISCS

NHK and Sanyo showed their jointly developed laser-scanned video disc system. The compressed Muse signal is recorded using frequency modulation, in a manner similar to that used for Philips Laservision. The two systems have much in common. There are two types of disc available: constant linear velocity (c.l.v.) and constant angular velocity (c.a.v.), giving recording times of about 17 and 30 minutes respectively. This, by comparison with a PAL-encoded Laservision disc, represents about half the playing time. As one would expect from such a system, the results were of a very high standard.

This NHK developed converter allows Muse signals to be displayed on a standard NTSC receiver. That the quality of display ultimately depends upon the receiver used was obvious from the NTSC-type defects that were visible. Perhaps the over-statement of the conference was that, "Muse is a simple system". This was difficult to believe, judging by the size of this converter.

H.D.TV TRANSMISSION VIA OPTICAL FIBRES

This rather over-engineered demonstration involved transmitting full-bandwidth h.d.tv signals over 1km of optical fibre. The signals were in the RGB and sync. format, with each component being transmitted over one of five fibres, using analogue modulation of the optical signal. Although transmissions of over 30km have been demonstrated before and the five components could have been coded into composite form for transmission over a single fibre, the demonstration clearly showed how it was possible to transmit h.d.tv signals through an electrically noisy environment, such as is sometimes found between the studio and the transmitter facility.

MULTIPLEXED ANALOGUE COMPONENTS (MAC)

Digital Video Systems Corporation of Canada presented two separate demonstrations based on the B-MAC format. The first one showed a working Wide-MAC system in 525-line format, using a video base bandwidth of 10MHz. The receiver decoder accepts a dual-aspect-ratio signal; either standard 4:3 or Wide-MAC 16:9 and provides outputs either as 4:3 NTSC or 16:9 in RGB component form. In the case of the 16:9 input signal, the decoder can select an appropriate segment of the image signal to convert into NTSC format.

The second demonstration was a computer simulation of an evolutionary and Wide-MAC-compatible step towards high-definition B-MAC (HDB-MAC). A line-differencing technique is used to generate the extra information to double the line rate to 1050 and at the same time, considerably improve the vertical resolution. As this demonstration was based on stills, it was difficult to evaluate the improvement in picture quality relative to those demonstrations based on moving images. However the improved resolution and lack of defects in HDB-MAC was obvious.

ADVANCED COMPATIBLE TELEVISION (ACTV)

The David Sarnoff Research Centre (GE,NBC,RCA), provided an impressive demonstration of Extended-Definition TV (e.d.tv) that is completely NTSC compatible. The source material was provided from an h.d.tv video tape recorder, but the system can accept either interlaced or progressive (sequential) scanning with either 5:3 or 16:9 aspect ratios. The viewer was presented with both wide-screen and standard receivers side by side, so that it was possible to make direct comparisons. Apart from the wider aspect ratio, the most obvious improvements were the lack of the usual NTSC characteristics, no visible line structure, reduced flicker, dot-crawl and noise, together with a significant improvement in resolution. Basic parameters of this system are 1050 lines per frame, 59.4 fields per second, 12.4MHz luminance bandwidth and 3.75MHz and 1.25MHz for the I and Q chrominance channels respectively. The system, as demonstrated, yields a vertical resolution in excess of 420 lines per picture height. It was stated that if a wider bandwidth was available, then this could be extended to about 750 lines, making it equivalent to the Muse system. These improvements are made by replacing certain picture information with details that are perceptually more important to the eye. The wide-screen source signal is digitized, filtered and converted into 525 lines, 2:1 interlaced format and encoded into four components. These are than multiplexed in a suitable manner, to enable the complete signal to fit into a standard 6MHz channel. These four signal components, all 2:1 interlaced, are as follows (see also p.308):

1(a). A main signal with a 4:3 aspect ratio is taken from the central portion of the main video signal and time expanded to occupy all but 2μs of the active line period.

1(b). Low video frequencies from the two remaining side panels are time compressed to about 1μs each and then added before and after the central section. The luminance and chrominance signals are comb-filtered to ensure that the additional information can be fitted into the spectral holes of the composite central signal.

> **'Current display technology is 30 years more advanced than systems originally designed to convey the images . . .'**

2. An auxiliary signal is derived from the high video frequencies of each side panel, which are then time expanded to fill the active line period. In doing this, the bandwidth of this component is reduced to about 1MHz.

3. An auxiliary signal is derived from the high video frequencies between 5MHz and 6.2MHz which are down-converted to 1 to 1.2MHz.

4. A *Helper* signal that has been filtered and band limited to 750kHz is derived from the vertical luminance detail. In the wide-screen receiver, this is used to help reconstruct the missing lines to improve the resolution and eliminate any line flicker.

In the multiplexing process, components 2 and 3 are quadrature-modulated on to a relatively low-level sub-carrier and then added to component 1. The low sub-carrier level ensures that patterning due to beat notes will be minimal. This complex signal, along with component 1, is then used to quadrature-modulate the final r.f. carrier. A standard NTSC receiver processes only the central signal portion, the auxiliary signals either being lost in the 4:3 aspect ratio overscan or have negligible effect.

Complex signal processing does produce some defects, notably slightly jagged diagonal edges, a little flicker along diagonal edges and a small loss of resolution in some picture areas. These were pointed out during the demonstration and were expected to be minimized by modification to the filtering.

HDMAC-60/HDNTSC

The North American Philips Corporation have devised a hierarchical approach to h.d.tv. The system has been demonstrated recently at their New York Laboratory and the results of the work were reported in two conference papers. A sub-system known as HDMAC-60 is used for transmission through a satellite link, the signal then being transcoded into HDNTSC for network or cable distribution, using two standard 6MHz NTSC channels. The HDNTSC signal is completely compatible with a standard NTSC receiver. This evolutionary approach was decided upon for economic and social reasons. When NTSC, SECAM and PAL signals are transmitted by frequency modulation over a satellite link, the chrominance components are disproportionately affected by noise. Using the MAC concept, this particular problem disappears.

HDMAC-60 has a 525 lines per frame, 59.94 fields per second and progressive (sequential) scanning format, with a luminance bandwidth of 16.8MHz. The MAC time compression is used in a very flexible way to ensure that all signal components have a transmission base-bandwidth of 9.5MHz. Provision is made in the transmission multiplex to include CD quality, multi-channel digital sound, data, control signals and, if needed, encryption control.

The baseband complex consists of nine different components: high and low-resolution luminance; high and low-resolution chrominance U and V signals; a line differential (LD) signal; digital sound; sync and clamping. Each component receives a different degree of time compression or expansion to ensure that each has a transmission bandwidth of 9.5MHz. The high and low-resolution components are transmitted cyclically, to maximize the overall picture resolution. The LD signal is generated as difference between the current-line luminance signal and the average of the preceding and following lines. As this signal is used at the receiver to recreate the sequentially scanned picture, a receiver frame store is necessary.

For redistribution purposes, the HDMAC-60 signal is recoded into the HDNTSC format, occupying two 6MHz channels, one channel being NTSC compatible and the other carrying the resolution-extension signals. These include the side panels for the 16:9 aspect ratio, high-frequency luminance details, the LD component and digital signals. Since this channel does not require syncs or colour burst, the whole period is available for these auxiliary signals that give the system a resolution in excess of 480 lines per picture height.

EUROPEAN D-MAC DEVELOPMENTS

The European commitment to the MAC concept as the only acceptable evolutionary approach to h.d.tv was confirmed in three papers, one of which presented a viewpoint from the Independent Broadcasting Author-

Studio equipment for the NHK/Muse system (Sony Broadcast).

ity and BSB, the contractor to purchase satellites and produce programmes for the UK d.b.s. service. This paper outlined the D-MAC specification (the selected UK standard) and its effect on developments in the studio environment. Also included was the following time scale over which h.d.tv might develop in the UK.

Phase I, (1989-1992). Introduction of D-MAC service to standard PAL-system receivers, via a set-top converter.

Phase II, (1990-2000+). Introduction of a MAC/PAL integrated receiver at a cost of around £450.

Phase III, (1991-2000+). The introduction of a wide-screen service with 16:9 aspect ratio, but compatible with receivers for Phases I and II. Costs of around £1000 for new receivers in the early stage.

Phase IV, (1995-2000+). h.d.tv introduced using the HD-MAC format of 1250 lines, 50 fields/second and 2:1 interlace, but still compatible with the 625 line MAC format and Phase I, II, and III receivers. Cost of early stage receivers would not be less £1500.

A second paper, not strictly related to h.d.tv, presented the research work carried out by British Telecom into spectrum economy. This system, known as D2-SMAC, is intended for satellite transmission, but where the signal is ultimately required for redistribution over such a cable network. For this service, the received signal needs to have a higher C/N ratio than that required for direct DBS. D2-SMAC is based on D2-MAC, with the luminance and colour difference signals being produced in the same way. The aim of this new variant is to reduce the transmission bandwidth without loss of S/N ratio, so that four television channels can be frequency multiplexed into a single 36MHz transponder bandwidth. This has been achieved by sub-sampling (the S in SMAC) the luminance signal, discarding alternate samples and then time compressing the signal by 2:1, instead of the usual MAC ratio of 1.5:1, allowing time for the inclusion of an adaptive interpolation control signal (AICS) to instruct the receiver decoder how best to interpolate. The decoder is thereby much less 'intelligent' and complex.

In the receiver, the missing samples are interpolated, either vertically or horizontally, from adjacent pixels, according to the setting of a control bit in AICS, which has been derived during the encoding process by averaging the error of the four surrounding pixel interpolations and comparing this with a threshold value. Depending on this comparison, the control bit is set to 0 or 1 and this instructs the decoder to interpolate in the direction of minimum error.

'If two world standards emerge, this may be no bad thing . . .

To minimize the effects of noise in plain areas of the picture, a form of adaptive noise filtering is employed. Again, control for the corresponding receiver filter is via AICS. Additionally, non-linear pre-de-emphasis is applied to both the luminance and chrominance signal components.

PERSONAL REFLECTIONS

Because the NHK/Muse system formed such a large section of the demonstrations and papers and is the only system commercially in use, it is important to examine the impact and problems that might arise if it were adopted as a single world standard, the only alternative system on the horizon being a MAC-based one.

Because of the high costs involved, any such accepted system will have to stand the test of time, perhaps the next 30 to 40 years. But is such a single standard desirable? It is worth looking at the v.c.r. market before answering. Would either VHS or BETA produce such good quality images today, if either had been accepted as world standard, say eight years ago? The competition for market domination must surely be responsible for the current, high recording standard. Again, what effect might display device developments have on h.d.tv or even the television signal requirements? Could a flat, solid state type of display with digital addressing of pixels change the way in which images are synchronized? The evolutionary development path to h.d.tv thus becomes more critical than ever.

It is useful to recall the situation that existed in the UK during the 1930s. The adoption of the "high-definition" 405 line system may be remembered for the way in which it stifled UK developments well into the 1960s. If Muse were chosen now as a world standard, and Muse after all is a compromise, would not such a situation arise world wide? Brilliant though the concept is, it now becomes pertinent to examine Muse for difficulties and defects. Movement interpolation is an important feature of this system and herein lies one problem: where multiple movements are present, particularly when accompanied with signal-level variations, a defocussing effect becomes noticeable. Probably because of the filtering techniques in use, diagonal stripes and diagonal movements give rise to a strobing effect and blurring. No doubt in time these will be resolved. Muse is designed to operate with a C/N ratio greater than 20dB; when this falls below about 14dB, colour changes become annoying. One well known West German researcher asked whether Muse had chosen the optimum chrominance components – no answer was forthcoming. Does this fact not mean that the system will need a larger antenna for satellite applications?

MAC, the European challenger, is currently being extensively researched and developed, but then so are several NTSC-based systems. Could there not be a place for E-PAL, the system developed by the BBC back in 1981/2? All this shows that considerable improvements can be made on current systems. Digital processing, which can be used for line-rate doubling, and a change from interlaced to progressive scanning are just two of the possibilities that have been demonstrated.

If two world standards emerge, this may be no bad thing, provided that a common, standard conversion medium can be developed to ensure that programme exchanges can be made.

One final question is worth considering. Where do these h.d.tv developments leave 16mm and 35mm film? The answer might well be that film is in a unique position. Telecine, after all, has proved to be an efficient and clean standards-conversion process for current television systems. It might well fill this role in h.d.tv and, at the same time, provide a means of releasing television productions into the cinema.

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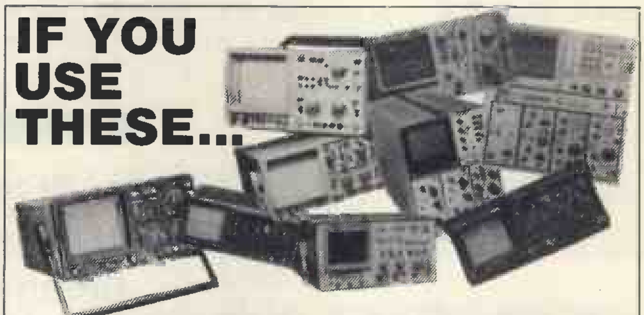

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PC-based instrument control systems

Availability of PC-based software dedicated to instrument control means that the PC has now become an ideal tool for use in instrument control applications.

STEVE STAMPS

Soon after the introduction of the IBM-PC in 1980 an IEEE-488 interface card was released by IBM to allow control of IEEE instruments. Since then a number of manufacturers, most notably National Instruments, Hewlett Packard and Tecmar, has released IEEE PC cards. These cards typically cost around a few hundred pounds and are supplied with set of software drivers to allow control of the card from the PC. They provide the full IEEE-488 mechanical and electrical interface, but are often limited by the documentation and software supplied with the card.

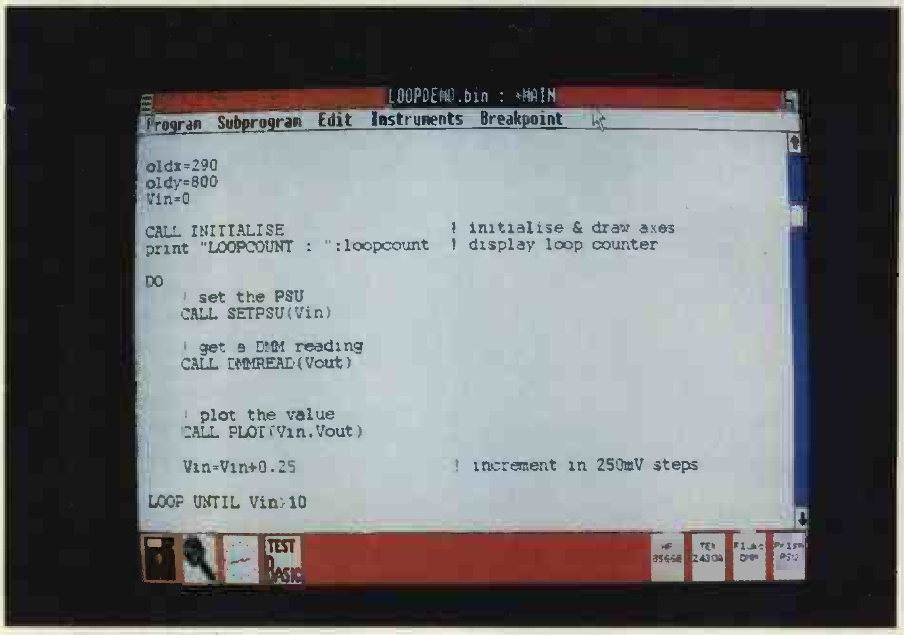
The cards have the advantage of being quick, cheap and simple to use for small projects, but have many disadvantages compared against a dedicated controller when used in larger projects. The software supplied can be difficult to use and debug in applications involving a number of instruments. As a result of these difficulties some users have considered using the PC as an instrument controller but concluded that, despite the benefits of the PC standard, a dedicated instrument controller is the best tool for serious applications.

Clearly the functions of a PC-based instrument controller depend almost entirely on the software provided for development and operation of instrument control programs. Whilst all IEEE-488 cards support the full electrical and mechanical standard, it is the software that provides the user-interface, application language and debugging tools which distinguish a good instrument controller.

Until recently the software available for instrument control was rather limited; in many cases the software supplied with IEEE cards looked as though it were an afterthought bundled into a package merely to encourage sales of interface cards. Now that a number of new software products dedicated to instrument control applications exist, we take a look at the leading three.

TESTWINDOWS

A software package that provides all the functions of a dedicated instrument controller on a PC, with the added benefit of 'windowed' development and debugging is TestWindows. It uses TestBasic, a highly structured Basic-like language designed specifically for instrument control, to provide the advantages of structured programs yet retain the benefits of an interpreted language to allow interactive testing of programs where necessary. TestBasic includes many of the features of structured languages such as Pascal, including the concepts of sub-programs and libraries to allow commonly used routines to be built up and called from other programs.



```
oldx=290
oldy=800
Vin=0

CALL INITIALISE                         ! initialise & draw axes
print "LOOPCOUNT : ":loopcount          ! display loop counter

DO
    ! set the PSU
    CALL SETPSU(Vin)

    ! get a DMM reading
    CALL DMMREAD(Vout)


    ! plot the value
    CALL PLOT(Vin.Vout)

    Vin=Vin+0.25                        ! increment in 250mV steps

LOOP UNTIL Vin>10
```

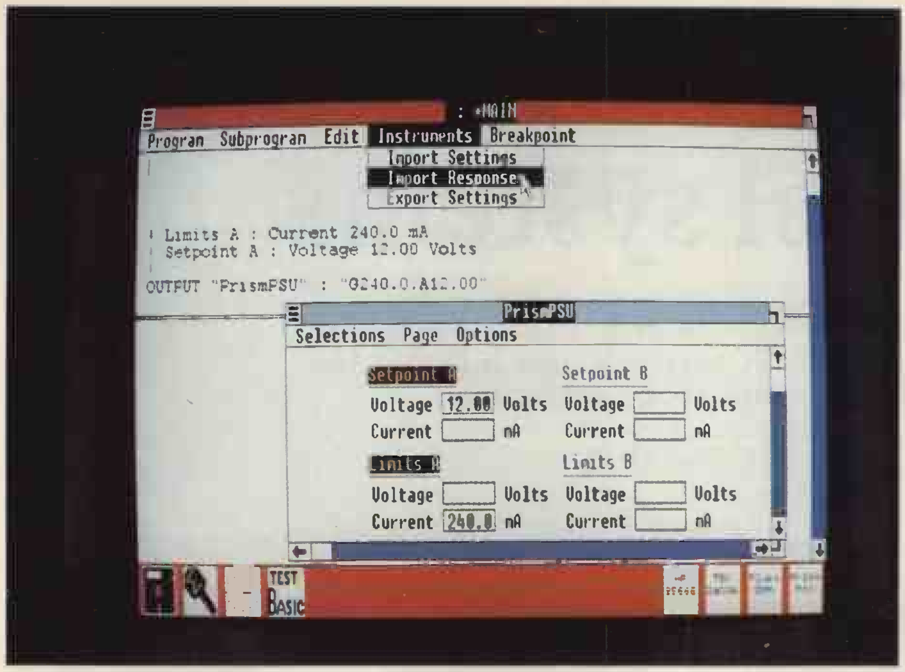
TestWindows converts an IBM-PC into a high-performance instrument controller. It uses TestBasic, a structured language designed for instrument control, for ease of programming.

The windowed environment allows multiple windows, such as the program editor, debuggers and output screen all to be displayed simultaneously on the PC screen. This means, for instance, that the source code can be displayed at all times without having to refer back to often outdated program listings.

The use of windows allows a number of powerful debugging features to be incorporated. The user can open up windows on the screen to trace the source code, variables, program stack, or even the interface bus itself whilst a program is running. The trace-code facility, for example, displays the source code in a window and highlights each line as it executes. This makes program control flow problems, where execution of a program continues at the wrong place, very much easier to track down. The trace window allows monitoring of the interface bus as a program is executed; this allows the response from each instrument to be monitored as it occurs.

A common problem when developing instrument control programs is the need to work with a large number of instruments, each with a different command language. The command to program an output voltage of five volts on one power supply, for instance, may be "V5.00" whereas another supply, perhaps from a different manufacturer, may require "VA5". This means that programming and debugging an instrument control program can require constant reference to the IEEE section of each instrument manual. If this is not in itself enough of a problem, in many situations it can often be difficult even to find the manual for some instruments!

TestWindows overcomes the problem of

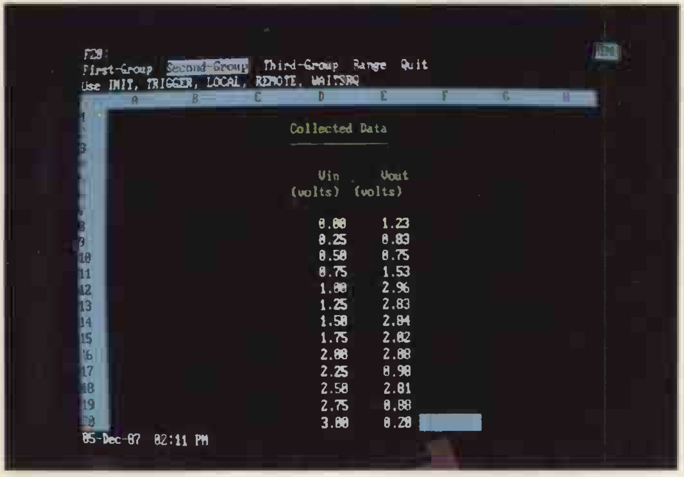


```
! Limits A : Current 240.0 mA
! Setpoint A : Voltage 12.00 Volts
!
OUTPUT "PrismPSU" : "G240.0.A12.00"
```

Setpoint A
Voltage 12.00 Volts
Current mA
Limits A
Voltage Volts
Current 240.0 mA

Setpoint B
Voltage Volts
Current mA
Limits B
Voltage Volts
Current mA

Instrument windows allow instruments to be set up using an on screen representation of the instrument front panel. The settings can be automatically converted into TestBasic commands, complete with comments, to perform the setup.



```
Collected Data

  Vin     Vout
(volts)  (volts)

  0.00     1.23
  0.25     0.83
  0.50     0.75
  0.75     1.53
  1.00     2.96
  1.25     2.83
  1.50     2.84
  1.75     2.82
  2.00     2.00
  2.25     0.98
  2.50     2.01
  2.75     0.88
  3.00     0.20
05-Dec-87 02:11 PM
```

Lotus Measure interfaces test and measurement equipment to the Lotus 1-2-3 spreadsheet. Using Measure, the collected data is inserted straight into a spreadsheet for analysis, archiving or display.

programming commands by providing a feature called 'instrument windows' to generate the commands automatically. Each instrument in a system can be programmed from a window on the PC screen that represents the front panel of the instrument. To set up an instrument you simply use the window just like the front panel of the instrument; the settings can then be sent to the instrument via the IEEE interface to confirm the setup. Once the correct settings have been entered, TestWindows can automatically generate the Basic program required to set up the instrument. It also generates comments to explain what the setup does and stores these alongside the instrument commands in the program.

TestWindows is an example of a software package which offers a serious alternative to a dedicated instrument controller. It combines all the functions of a dedicated controller with the benefits of the IBM-PC standard.

ASYST

Asyst is a PC software package for data capture and analysis, and is well suited to scientific and engineering applications where off-line analysis and manipulation of collected data is required. It includes a set of very powerful scientific data analysis capabilities to manipulate collected data without the user becoming directly involved in complex mathematical operations.

Asyst interfaces to instruments via the IEEE-488 or RS232 interfaces or can interface to PC-based digital and analogue data acquisition cards. With Asyst you can either perform data acquisition, analysis and display interactively or can write Basic-like programs to perform a predefined set of operations automatically.

The analysis capabilities provided as standard include polynomial evaluation, matrix manipulation, curve fitting and fast Fourier transforms. These are provided as standard functions which can be called in the same way as normal mathematical operations. The graphics and display facilities of Asyst allow complex graphs and tables to be displayed on the PC screen and multiple sets of data can be overlaid to compare results or curve fitting functions.

Asyst converts the PC into a powerful, data capture and analysis workstation. It is an example of an easy to use package for instrument control that still manages to be extremely flexible.

LOTUS MEASURE

The launch of Lotus Measure illustrates that major software vendors, such as Lotus, are beginning to realise the potential of the PC in engineering and scientific applications. Lotus Development Corporation have, in fact, recently formed a new division dedicated to providing software products specifically for such applications.

Lotus 1-2-3 has become almost an industry standard software package for spreadsheet, graphics and database applications. In recognising the needs of engineering and scientific users Lotus have developed a package to interface Lotus 1-2-3 to the world of test and measurement, allowing the user to automate the collection, analysis and presentation of data.

Before the introduction of Measure, the quickest way to acquire a set of short, simple measurement results was to take the readings manually and transcribe the data by hand into a spreadsheet or graphics package. This method can be slow, tedious and prone to transcription errors, and it is often desirable to automate the collection in some way.

Lotus Measure controls instruments and collects data, in real time, via either the IEEE-488 or RS232 interfaces, or can connect directly to transducers via a PC data acquisition card. Data can be acquired from within a Lotus 1-2-3 session either interactively, using new 1-2-3 commands provided by Measure, or by writing instrument control programs in Lotus macro command language.

Using the macro facility complete data acquisition systems can be written to automatically perform tests and measurements and store results in Lotus 1-2-3 format. The existing 1-2-3 commands and facilities can be used to analyse and present the collected data.

Measure is fully compatible with other Lotus products, allowing collected data, for instance, to be automatically inserted into documents and reports using Lotus Manuscript, a technical word processor.

Lotus Measure is a good example of the new breed of PC software products that are now becoming available for engineering and scientific applications. The economies of scale when developing a volume product mean that a high degree of functionality can be incorporated. Many of the major PC software companies, such as Lotus, are now beginning to realise the potential of the PC as an instrument controller; we can expect to see further developments in this area in the future.

Steve Stamps is a director of Integrated Measurement Systems of Southampton, which specializes in measurement, test and control systems and software.

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The L296 and L4960 high-power switching regulators from SGS allow the design of simple, economical multiple-output power units.

SUE CAIN and RAY AMBROSE

Most of the switching regulators produced today have multiple outputs. The output voltages most frequently used – at least for powers up to 50W – are +5V, −5V, +12V and −12V. In these supplies the 5V output normally delivers the highest current and requires the highest precision; for the other voltages – particularly the negative outputs – less precision (±5% ±7%) is usually sufficient. Often, however, for high-current, 12V outputs, better stabilization and greater precision (typically ±4%) are required.

Traditionally, these have been achieved using a number of components. However, the SGS L296 and L4960 high-power switching regulator i.cs have been designed specifically as multiple-output supplies which satisfy these requirements. Several practical supply designs are described below to illustrate how these components are used to build compact and inexpensive multi-output supplies.

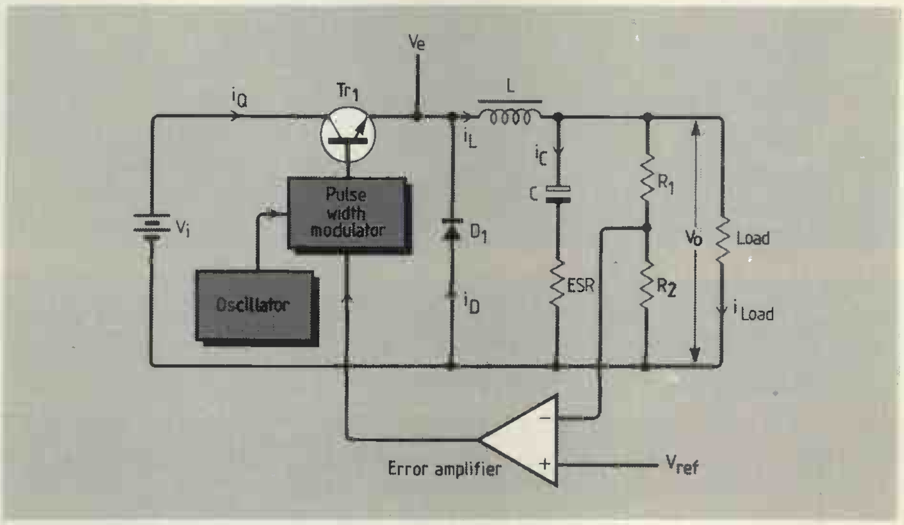


Fig. 1. Basic step-down configuration

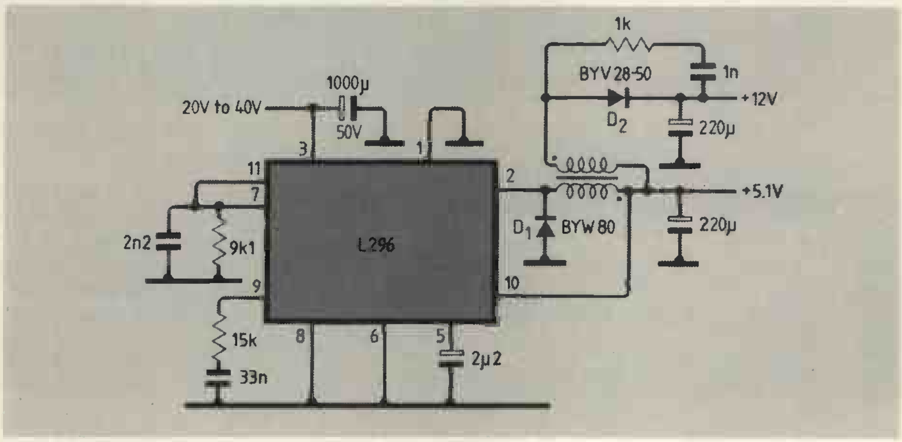


Fig.2. Dual output d.c.-d.c. converter (5V/3A, 12V/150mA). The transformer consists of 30T (primary) and 40T on Magnetics 58930.

L296 AND L4960 HIGH-POWER SWITCHING REGULATORS

The L296 is a monolithic, stepdown, switching regulator assembled in the 15-pin Multiwatt package. Operating with supply input voltages up to 46V, it provides a regulated 4A output variable from 5.1V to 40V.

Internally, the device is equipped with current limiter, soft start and reset (or power fail) functions, making it particularly suitable for supplying microprocessors and logic. The precision of the internal reference (±2%) eliminates the need for external dividers or trimming to obtain a 5V output. A synchronization pin allows synchronous operation of several devices at the same frequency to avoid generating undesirable beat frequencies.

The L4960 is a similar device assembled in the 7-lead Heptawatt package. Like the L296 it has a maximum input voltage of 46V and it provides a regulated output voltage variable from 5V to 40V with a maximum load current of 2.5A. Current limiting, soft start and thermal protection functions are included.

The thermal protection circuit in both the L296 and L4960 has a hysteresis of 30°C to allow soft restarting after a fault condition.

STEP-DOWN CONFIGURATION

Figure 1 shows the basic structure of a step-down switching regulator. The transistor is used as a switch and the On and Off times are determined by the control circuit. When the transistor is saturated, current flows from the supply, V_i, to the load through the inductor L. Neglecting the saturation voltage of the transistor, $V_e \simeq V_i$.

When the transistor is Off, current continues to flow in the inductor L in the same direction, forcing the diode into conduction immediately; therefore V_e is negative. In these conditions, the load current flows through L and D.

The average value of the current in the inductor is equal to the load current. In the inductor, a triangular current ripple equal to $\triangle I_L$ is added to this average current.

During the time when the transistor is On, this ripple is

$$\triangle I_L = \frac{(V_i - V_o)\,T_{ON}}{L}$$

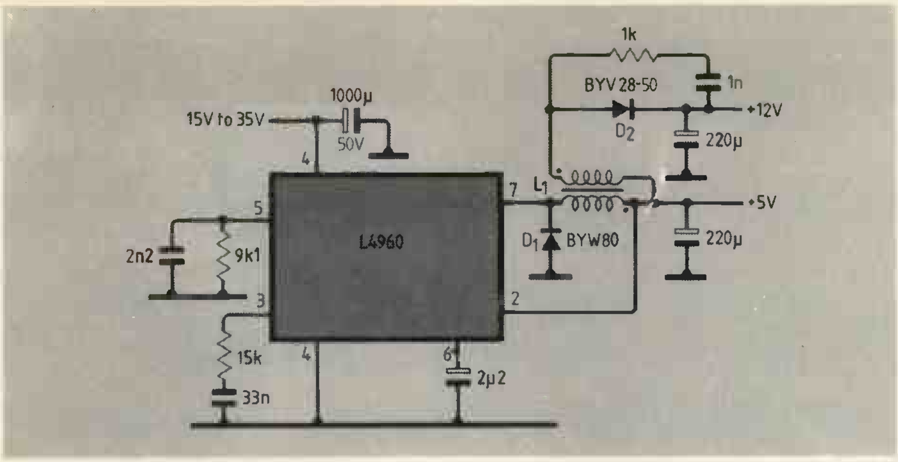


Fig.3. Dual output d.c.-d.c. converter (5V/1.5A, 12V/100mA). Transformer, with same number of turns, is on Magnetics 58206.

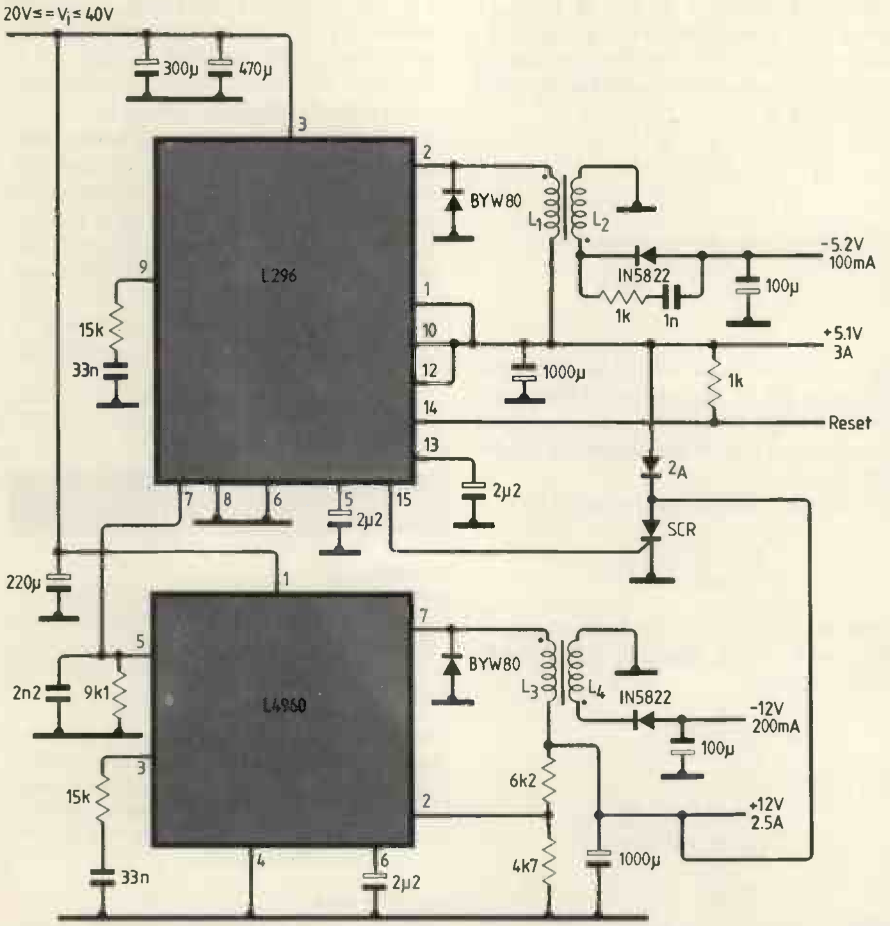


Fig.4. Multi-output d.c.-d.c. converter with L296 and L4960 (5V/3A, 12V/1.5A, −12V/100mA, −5V/100mA).

and when the transistor is off,

$$\Delta I_L = \frac{V_o \cdot T_{OFF}}{L}$$

Equating these expressions and assuming that the transistor and diode are ideal we obtain:

$$V_o = V_i \cdot \frac{T_{ON}}{T}$$

where T_{ON} is the conduction time of the transistor and T is the oscillator period.

The absolute average current in the supply is therefore

$$I_{ioc} = I_o \cdot \frac{T_{ON}}{T}$$

Once the working frequency and desired ripple current have been fixed, the value of the inductor L is given by

$$L = \frac{(V_i - V_o)\, V_o}{V_i\, f\, \Delta I_L}$$

and the value of the capacitor C required to give the desired output voltage ripple (ΔV) is

$$C = \frac{(V_i - V_o)\, V_o}{8\, L\, f^2\, \Delta f_o}$$

This capacitor must have a maximum

Table 1. Performance obtained with a dual
output 15W supply

Parameter		V_{01}	V_{o2}	Unit
Output voltage $I_{o1}=3A$	$V_i=30V$ I_{o2} 150mA	5.120	12.089	[V]
Output ripple		70	40	[mV]
Line regulation $I_{o1}=3A$	$20V \leq V_i \leq 40V$ $I_{o2}=150mA$	15	30	[mV]
Line regulation $I_{o1}=700mA$	$20V \leq V_i \leq 40V$ $I_{o2}=100mA$	15	10	[mV]
Load regulation $I_{o1}=700mA \rightarrow 3A$	$V_i=30V$ $I_{o2}=150mA$	10	130	[mV]
Load regulation $I_{o1}=700mA$	$V_i=30V$ $I_{o2}=100 \rightarrow 150mA$	0	40	[mV]
Load regulation $I_{o1}=3A$	$V_i=30V$ $I_{o2}=100 \rightarrow 150mA$	0	40	[mV]
Efficiency	$V_i=30V$ $V_{o1}=5.120V$ $I_{o1}=3A$ $V_{o2}=12.089V$ $I_{o2}=150mA$	75		%

Table 2. Performance with a dual output 7.5W supply

Parameter		V_{01}	V_{o2}	Unit
Output voltage $I_{o1}=1.5A$	$V_i=25V$ I_{o2} 100mA	5.050	12.010	[V]
Output ripple		50	30	[mV]
Line regulation $I_{o1}=1.5A$	$15V \leq V_i \leq 35V$ $I_{o2}=100mA$	7	75	[mV]
Line regulation $I_{o1}=500mA$	$15V \leq V_i \leq 35V$ $I_{o2}=50mA$	7	60	[mV]
Load regulation $I_{o1}=0.5A \rightarrow 1.5A$	$V_i=25V$ $I_{o2}=100mA$	3	100	[mV]
Load regulation $I_{o1}=500mA$	$V_i 25V$ $I_{o2}=50mA \rightarrow 100mA$	0	55	[mV]
Load regulation $I_{o1}=1.5A$	$V_i=25V$ $I_{o2}=50mA \rightarrow 100mA$	0	50	[mV]
Efficiency	$V_i=25V$ $I_{o1}=1.5A$ $I_{o2}=100mA$	78		%

Table 3. Performance using a 30W d.c.-d.c. converter

Parameter		V_{01}	V_{o2}	V_{o3}	V_{o4}	Unit
Output Voltage $Io_1=3A$ I_{o2} 100mA	$V_i=30V$ $I_{o3}=1.5A$ $I_{o4}=100mA$	5.080	−5010	11.96	12.00	[V]
Output ripple		50	30	50	40	[mV]
Line regulation $I_{o1}=1A$ $I_{o3}=0.5A$	$20 \leq V_i \leq 40V$ $I_{o2}=100mA$ $I_{o4}=100mA$	13	15	10	20	[mV]
Load regulation $I_{o1}=1A$ to 3A	$V_i=30V$ $I_{o2}=100mA$	8	90			[mV]
$I_{o3}=0.5$ to 1.5A	$I_{o4}=100mA$			3	80	[mV]
Load regulation $I_{o1}=3A$	$V_i=30V$ $I_{o2}=50 \rightarrow 100mA$	0	100			[mV]
$I_{o3}=1.5A$	$I_{o4}=50 \rightarrow 100mA$			0	100	[mV]
Load regulation $I_{o1}=1A$	$V_i=30V$ $I_{o2}=50 \rightarrow 100mA$	0	35			[mV]
$I_{o3}=0.5A$	$I_{o4}=50 \rightarrow 100mA$			0	90	[mV]
Line regulation $I_{o1}=3A$	$20 \leq V_i \leq 40V$ $I_{o2}=100mA$	15	45			[mV]
$I_{o3}=1.5A$	$I_{o4}=100mA$			15	40	[mV]

e.s.r. given by

$$\text{e.s.r.}_{MAX} = \frac{\Delta V_o}{\Delta I_L}$$

And finally, the minimum load current, $I_{O(MIN)}$ must be

$$I_{O(MIN)} = \frac{\Delta I_L}{2} = \frac{(V_i - V_o)V_o}{2V_i F_L}$$

DUAL-OUTPUT 15W SUPPLY

A single L296 is used in this application to produce two outputs, V_{o1} at 5V/3A and V_{o2} at 12V/150mA. The application circuit, Fig.2, illustrates how the second output (12V) is obtained by adding a second winding to the output inductor. Energy is transferred to the secondary during the recirculation period when the internal power device of the L296 is Off. Since the 12V output is not separated from the 5V output, fewer turns are necessary for the second winding; therefore, less copper is needed and load regulation is improved.

In applications of this type it is a good rule to ensure that the power drain on the auxiliary output is no more than 20-25% of the power delivered by the main output.

Table 1 shows the performance obtained with the dual-output supply. The circuit operates at a switching frequency of 50kHz.

DUAL-OUTPUT 7.5W SUPPLY

The same technique – adding a secondary winding – can also be used to produce an economical and simple dual output supply (V_{o1}=5V/1.5A, V_{o2}=12V/100mA) with the L4960, a device containing the same control-loop blocks as the L296 and 2A output stage (Fig.3). Though this circuit costs very little, the performance obtained (see Table 2) is more than satisfactory. The switching frequency is 50kHz.

30W D.C.–D.C. CONVERTER

Designing power supplies in the 30-40W range is becoming increasingly difficult, because it is here that there is the greatest need to maintain performance levels and reduce costs. The application proposed here is very competitive since it exploits new i.cs to reduce size, number of components and assembly costs.

The cost of this solution, the d.c.-d.c. converter, compares very favourably with off-line switching supplies. D.c.-d.c. converters can be realised even by designers with little experience and allows the convenience of working with low voltages. Off-line switching supplies are only preferable when the weight and size of the mains transformer in a d.c.-d.c. converter would be excessive.

In this circuit, shown in Fig.4, two devices are used, an L296 and an L4960. The L296 is used to supply a 5V output with a current of 3A and the auxiliary −5V/100mA output, and the L4960 is used to provide the 12V/1.5A output and the auxiliary −12V/100mA output.

Table 3 shows the performance obtained with this power supply. This application illustrates how two devices may be synchronized. In this case, the reset circuit is used to monitor the output voltage: if a power fail function is required in place of the reset function the Figure 4 circuit should be modified as shown in Figure 5.

POWER FAIL TIME

The 'power fail time' is defined as the time from when the power fail output (pin 14) goes low to the time when the input voltage falls to the minimum level required to maintain the regulated output. From this definition we can evaluate the energy balance.

The energy which the filter capacitor C supplies to the operating device while it discharges is:

$$E = ½C\,(V_1^2 - V_2^2)$$

The load drains a power of P_o=V_oI_o. Taking into consideration the average efficiency η (derived with the input between V_1 and V_2), the power to be supplied at the input of the device is:

$$P_{o2} = \frac{P_o}{\eta}$$

Equating these two expressions gives

$$½C\,(V_1^2 - V_2^2) = \frac{P_o}{\eta} \cdot t_{PF}$$

where V_i is the input voltage at which the voltage on pin 12 reaches 5V (through the divider R_1/R_2); V_2 is the maximum input voltage below which the device no longer regulates.

Rearranging this expression to obtain C

$$C = \frac{2P_o t_{PF}}{\eta(V_1^2 - V_2^2)}$$

For example, if V_o = 5V, I_o = 3A, T_{PF} = 10ms and V_i = 35V. Fixing V_1 = 25V and V_2 = 10V we obtain:

$$C = \frac{2P_o t_{PF}}{\eta(V_1^2 - V_2^2)}$$

$$= \frac{2 \times 15 \times 10 \cdot 10^{-3}}{0.75\,(25^2 - 10^2)}$$

$$= 760\mu F$$

We therefore choose a capacitor of 1000μF.

CROWBAR

The L296 includes an internal crowbar function, for which the only external component needed is an s.c.r. The intervention threshold of this block is fixed internally at ±20% of the nominal value of the internal reference.

In the Fig. 4 circuit, the s.c.r. is triggered by an over-voltage on the 5V output (usually the most important output to monitor) and short-circuits to ground the 5V output and, through the diode which connects the two outputs, the 12V output.

Since the internal current limiter in the device is designed to function with pulsed output current, the s.c.r. turns off in the gap between pulses and is re-activated if, when the device restarts softly, the fault condition has not been eliminated. But, if the fault no longer exists the s.c.r. remains Off and the output voltage returns to the normal value.

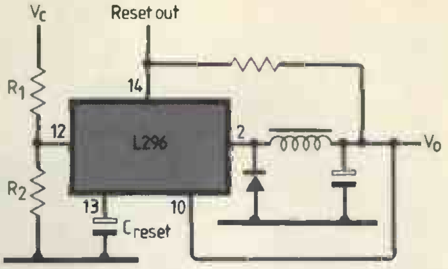


Fig.5. Modification of a multioutput d.c.-d.c. converter with L296 and L4960 in order to produce a power-fail function.

If the designer prefers the supply to remain off after the s.c.r. has been activated, the circuit can be modified in such a way that, when the s.c.r. is triggered, a very high current flows in the fuse, blowing it.

Since the filter capacitor can have a high value and be charged to high voltages, the choice of s.c.r. is important. The type used in this circuit – the TYP512 – is a plastic-packaged s.c.r. able to handle 12A r.m.s. and 300A for 10ms. The maximum forward and reverse voltages are about 50V.

If the crowbar circuit is not used it is advisable to connect pin 1 to ground or pin 10.

Sue Cain is with BA Electronics, and Ray Ambrose is with SGS.

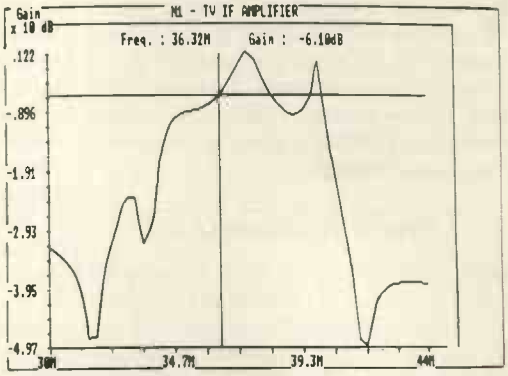
EXHIBITIONS & CONFERENCES

March 8 to 10
CIE 88. Components in electronics exhibition, officially supported by AFDEC, the association of electronics component distributors. Business Design Centre, Islington, London. Nutwood Exhibitions, Tel: 04868 25891.

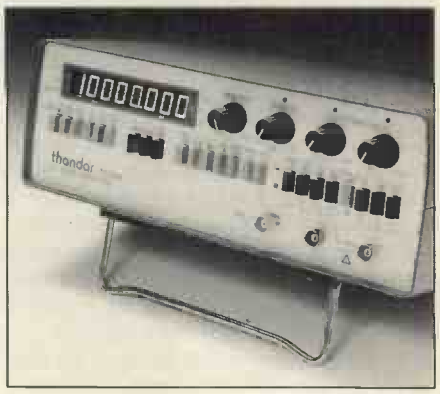
March 16 to 23
Hanover Fair CeBIT 88. International exhibition of Office, information and communications technology. Details from Deutsche Messe and Ausstellungs AG. Messegelander, D-3000 Hanover 80. Federal Republic of Germany.

March 21 to 24
Video, audio and data recording. Seventh international conference at the University of York. Organized by the IERE, Tel: 01-388 3071.

March 22 to 24
Internepcon production show and conference. Electronics components, power supplies, rack and enclosures. NEC Birmingham. Cahner Exhibitions, Tel: 01-891 5051.
Into 88. Industrial training opportunities show and conference. A showcase for training establishments with an emphasis on improving efficiency in industry by training. NEC Birmingham. Emap International Exhibitions, Tel: 01-404 4844.
OCC 88. Offsore computers conference and exhibition. Aberdeen Exhibition and Conference Centre. Offshore Conferences, Tel: 01-940 6211.
Radionav 88. International conference of the Royal Institute of Navigation. City University, Manchester Square, London EC1. Details from the Institute, Tel: 01-589 5021.



Gain
x 10 dB
M1 - TV IF AMPLIFIER
Freq. : 36.32M
Gain : -6.10dB
.122
-.896
-1.91
-2.93
-3.95
-4.97
30M
34.7M
39.3M
44M



Einstein and the ether

Relativistic theory does not reject the existence of an ether. Dr Kostro, of the Institute of Experimental Physics, Gdansk University, has undertaken extensive research into Einstein's views; that his model of space-time is a model of a new ether.

LUDVIK KOSTRO

Viewpoints are often expressed in *Electronics and Wireless World* which assume that Einstein's theory and the existence of an ether are conflicting and incompatible. It is time, therefore, that some of the truths of historical record, concerning Einstein's views on the ether, were given a hearing.

'ETHER' TERMINOLOGY

This is a distortion of the truth. Einstein did deny the existence of the fixed and immobile ether of the nineteenth century, but he, nevertheless, in 1916, proposed a completely new conception of the ether. In a sense, one can say that he was provoked into doing this by the influence of H.A. Lorentz and P. Lenard.

Lorentz wrote a letter to Einstein in which he maintained that the general theory of relativity admits of a stationary ether hypothesis. In reply, Einstein introduced his new non-stationary ether hypothesis. He wrote to Lorentz on the 17th June 1916:

I agree with you that the general relativity theory is nearer to an ether hypothesis than is the special relativity theory. However, this new ether theory would not violate the principle of relativity, because its state $g_{\mu\nu}$ = aether would not be that of a rigid body in an independent state of motion, but its state of motion would be a function of position determined via the material processes[1].

Physical space (connected closely with time) whose state, in relativity theory, is described by the fundamental metrical tensor $g_{\mu\nu}$ is regarded by Einstein as the relativistic ether. Einstein did not publish his new ideas on this in 1916 or 1917 as he advanced his work on the general theory. The first appearance of the new conception in print was provoked by Lenard. In 1918 Lenard published a paper opposing Einstein's relativity theory[2] in which he maintained that in the general theory the disqualified ether came back under the new name 'space'. In reply Einstein wrote an essay[3] in which he published the above-presented new definition of the ether. Indeed, in the period 1918-1955 Einstein published about 15 papers in which he interpreted his models of space-time as models of a new ether.

In these papers we can discriminate three models of the relativistic ether:

The first is that of the special relativity theory. In the mathematical description of this ether the ten components of the $g_{\mu\nu}$ tensor are constant. The related ether is rigid, flat and infinite. Its metric is pseudo-Euclidean.

The second is that of the general relativity theory. In its mathematical description the ten components of the $g_{\mu\nu}$ tensor are no longer constant. The states described by the tensor can change not only from one place to the other, but also in time. This ether is no longer rigid and flat. Its metric is pseudo-Riemannian.

The third ether is that of the unitary relativistic field theory. In the mathematical description of this ether the symmetrical tensor $g_{\mu\nu}$ (where $g_{\mu\nu}=g_{\mu\nu}$) no longer describes the ether completely, because the geometrical structure of it is more than Riemannian. New structural elements have to be introduced for a complete description of the ether because it has to determine not only the inertio-gravitational phenomenona, but also electromagnetic actions.

Thus, since 1916, Einstein's physics of space, albeit incorporating time within the space dimension, became the physics of a new ether, a physical ether and not just a mathematical formulation. In this physics the three physical notions: 'space', 'ether' and 'field' have found their complete unification through consequent identification.

'Physical space and the ether are only different terms for the same things; fields are physical states of space'[4].

Einstein's conception of the ether constitutes a gradual conceptual activation, dynamization and materialization of the physical space. According to the new conception, in its most developed form, the physical space closely connected with time is not a passive and static container of events, nor is it a physically-indifferent or neutral arena of physical phenomena. It is an active dynamic field medium which determines the inertio-gravitational, electromagnetic and other processes, which include the production of elementary particles. The real physical space, as an active field medium of this kind, possesses energy and therefore mass as well and that is why it is itself of a material nature. It constitutes active matter *sui generis* for which the term 'ether' is the most appropriate name.

It must be mentioned, however, that the three synonyms: 'physical space', 'ether' and 'total field' were used by Einstein with different frequency in different periods:

In the period 1916-1925 (see e.g. refs 5,6) the term 'ether' was used very often. He maintained even that 'in a consequent field theory all objects of physics must be embraced in the notion of ether'[6].

In the period 1926-1935 (see e.g. refs. 7,8,9) the term 'physical space' played the principal part in Einstein's papers. He wrote: ***'Space, brought to light by the corporeal object, made a physical reality by Newton, has in the last few decades swallowed the ether and time and seems to swallow also field and corpuscles, so that it remains as the sole carrier of reality'***[7].

In the third period 1936-1955 (see e.g. ref 10) the term 'total field' or 'entire field' was the term preferred by Einstein. After 1925 Einstein began to use the word 'ether' less and less often, although he still wrote in 1938:

'This word ether has changed its meaning many times in the development of science... Its story, by no means finished, is continued by relativity theory'[11].

and although, in 1954, he still indicated that:

'rigid four-dimensional space of the special theory of relativity is to some extent a four-dimensional analogue of H.A. Lorentz's rigid three-dimensional ether'[12].

Yet, underlying all this was his statement dating from 1920, made in the light of his early work on both the Special and General Theories of Relativity that:

'There is an important argument in favour of the hypothesis of the ether. To deny the existence of the ether means, in the last analysis, denying all physical properties to empty space'[5].

According to Einstein's new conception, it was impossible to formulate a complete physical theory without an (at least latent) ether hypothesis, because every complete physical theory must take into consideration the real properties of the physical space i.e. the 'Milieu-Einflusse[6]'. One might not use the word 'ether' but one has still to recognize that physical space has real properties which play an active part in physical happenings and, therefore, Einstein maintains:

'The ether hypothesis was bound always to play a part even if it is mostly a latent one at first in the thinking of physicists'[5].

THE PHYSICAL ETHER

In Einstein's special relativity ether model the physical space accomplishes its active function by 'determining the inertial behaviour of a test body introduced into it'[12] and possesses 'the physical property of transmitting electromagnetic waves'[11], but 'it no longer stands as a medium built of 'particles'[11] or 'points'[6] and is no longer regarded as an immobile or stationary medium. The concept of motion cannot be applied to it, but:

'According to special relativity, the ether remains still absolute because its influence on the inertia of bodies and on the propagation of light is conceived as independent of every kind of physical influence'[6].

In Einstein's general theory the ether is no longer absolute in the above sense, because:

'it not only conditions the behaviour of inert masses but is also conditioned, as regards its state, by them'[5].

The general theory is incomprehensible without an active ether:

'According to the general relativity, space is endowed with physical qualities; in this sense, therefore, an ether exists. In accordance with the general theory of relativity space without an ether is inconceivable. For in such a space there would not only be no propagation of light, but no possibility of existence of scales and clocks, and therefore no spatio-temporal distances in the physical sense. But this ether must not be thought of as endowed with the properties characteristic of ponderable media, as composed of parts, the motion of which can be followed: nor may be the concept of motion be applied to it'[5].

The general relativity ether manifests its activity through its function determining the inertio-gravitational behaviour of material bodies and through the creation of elementary particles. A test body which is only under the influence of this physical space is at rest or follows a geodetic, curved or straight, respectively, in curved or locally-flat spaces of reference.

Einstein made several attempts to find solutions of general relativity field equations free of singularities which might be interpreted as presenting corpuscles. Together with Rosen, he found such solutions of the centrally-symmetrical gravitational field equations for both neutral and electrically-charged particles:

'The neutral, as well as electrical, particle is a portion of space'[13].

In Einstein's special and general theories the electromagnetic field appears as something which 'fills space'[12], i.e. as something which does not belong to the structure of the physical space described by the metrical tensor $g_{\mu\nu}$. Since Einstein came to regard real physical space as the 'total field' of all physical actions and not only the inertio-gravitational ones, he began to look for a unitary field theory, i.e. for:

'a theory of the continuum in which a new structural element appears side by side with the metric such that it forms a single whole together with the metric'[4].

Einstein often emphasized that the pseudo-Riemannian space-time described by the tensor $g_{\mu\nu}$ does not constitute a complete description of the physical space connected with time. He made several attempts to generalize it, e.g. through enriching Riemannian space by adding the relation of direction or parallelism.'[4] He was even convinced that he had 'found the most natural form for this generalization'[12] in his 'theory of the unsymmetrical field'.

However, although activity of the ether described by Einstein's unitary field theory is richer than that described by his general theory, because it also includes electromagnetic interactions, the view today is that Einstein's unitary field theory is unsatisfactory.

EVOLVING ETHER

On the basis of the principle of equivalence of energy and mass Einstein arrived at the conclusion that there is no qualitative difference between the real physical space and ponderable matter composed of particles. Real physical space, as an active field possessing energy (and therefore also mass) constitutes an active matter *sui generis* i.e. an ether. According to Einstein:

'The strange conclusion to which we have come is this – that now it appears that space will have to be regarded as a primary thing and that matter is derived from it, so to speak, as a secondary result. Space is now having its revenge, so to speak, and is eating up matter'[9].

The message here is that we are involved with an ether that can materialize as matter, but although time is merged with space in Einstein's theories and the time dimension appears in the connection between mass and energy, the question of a state of motion of the ether poses problems. Although the notion of motion cannot be applied to space as such, space is never passive. It is an ever-active medium conceived by Einstein as non-atomic and non-mechanical in character but yet as being the fundamental source of every physical activity, the creation of particles included.

In following Einstein's research on this theme one finds that Einstein's relativistic ether is something ultra-referential. It does not constitute a reference frame and has not a proper reference frame. If it had it would be at rest in it, and yet it is not a stationary ether. The ultra-referential time is not composed of moments, just as the ultra-referential space is not composed of points. A moment constitutes a set of simultaneous events which belong to it. Since, in the theory of relativity, simultaneity is a strictly relative thing, the ultra-referential time cannot be composed of moments. Nevertheless, the ultra-referential time is something 'extended' composed of past, present and future. With respect to a freely chosen event considered as present, there exists always a set of events which are absolutely past and a set of events which are absolutely future. Every reference time is one of the possible orientations in the ultra-referential time. It is analogous to the relationship that exists between reference spaces in the ultra-referential space. These reference spaces are quasi-objects which move with respect to each other but not with respect to the ultra-referential space. Yet it is the physical characterization of the latter that is what may be said to be a more fundamental reality. According to Einstein, the ultra-referential space identified with ether is not something that can be divided into separate parts, nor does it constitute a universal quasi-object.

Einstein's presentation of this activity (which extends beyond his treatment of the inertio-gravitational effects) cannot be considered today as satisfactory. His research on this point cannot be regarded as accomplished in any definite way. Nowadays, this programme is continued in those hypotheses in which the elementary particles are presented as solitons superimposed on Einstein's relativistic ether. We find models of elementary particles in which de Broglie waves are interpreted as real waves in Einstein's relativistic ether e.g. in the works of J.P. Vigier[14] and L. Kostro[15,16,17]. The author's 'three-wave model of the elementary particle' constitutes an attempt to develop some ideas of Einstein in which elementary particles are conceived as 'fields of a particular kind which are particular states of space'[6]. In the 'three-wave model' elementary particles are presented as particular threefold wave fields in Einstein's relativistic ether.

Einstein's ether is not the unique ether conception of the twentieth century. We find similar relativistic ethers in the works of H. Weyl and A.S. Eddington. In 1951 a new ether conception was introduced by P.A.M. Dirac[18]. The most recent ether conception is that of H. Aspden[19,20], in which the ether constitutes 'a structured vacuum determining universal physical constants.'[19]. As we see, therefore, the notion of the ether was not destroyed by Einstein, as the general public believe. Research on the ether question is very much alive and it remains to be seen how much of Einstein's influence will feature in the future development of ether theory.

The author would like to express his sincere thanks to the Volkswagen Company for financial support which made this author's research into Einstein's relativistic ether possible.

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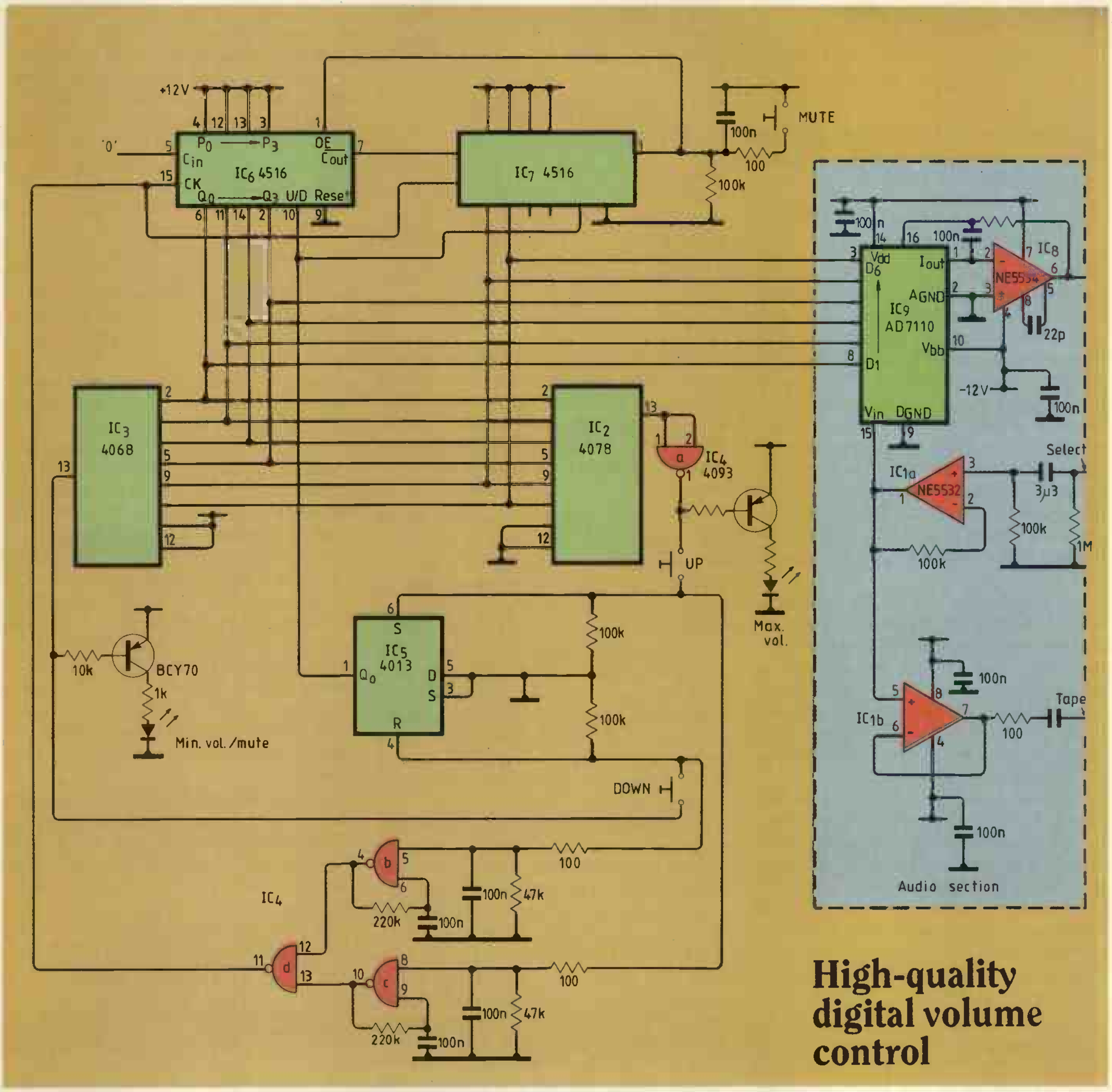


High-quality digital volume control

Circuitry based on a multiplying d-to-a converter provides a digital volume control with 0.01% distortion and better than 100dB signal-to-noise ratio. Attenuation of the control ranges from 0 to 88.5dB in 1.5dB steps, and being programmed by up/down push buttons, the design is easily adapted for remote-control applications.

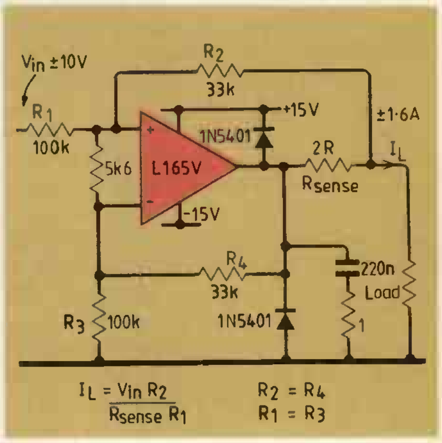
Analogue input is first buffered by a low-noise amplifier; the resulting signal feeds the d-to-a converter and a second amplifier providing a tape-recorder output. Within the d-to-a converter, the analogue signal is converted to a proportional output current that is then converted back to voltage by a further low-noise amplifier.

Presettable up/down counters $IC_{6,7}$ produce six control bits. At power up, or if the mute button is pressed, the counters are

Power current source and sink

With the addition of a few resistors, the L165V power op-amp forms a voltage-controlled current source/sink for up to 3A. To reduce loop gain and ensure stability, a resistor is inserted between the op-amp's inputs. Two diodes are included to make the circuit suitable for inductive loads. For output currents greater than 1.65A, R_{sense} needs to be reduced.

D. Howson
Great Sutton
South Wirral



loaded with a value representing maximum attenuation. Pressing either the up or down button causes IC_5 to set the appropriate count direction. After a short delay, clocking of the counters starts and the attenuation level changes. To prevent the counters from 'rolling over', $IC_{2,3}$ are included to detect all zeros and all ones states.

Analogue switches connected to the up/down push buttons could be used for remote control. Only one digital control circuit is needed to control a number of analogue sections.

Alan J. Jones
Newcastle-under-Lyme
Staffordshire

8048 switch-reading and interrupt tips

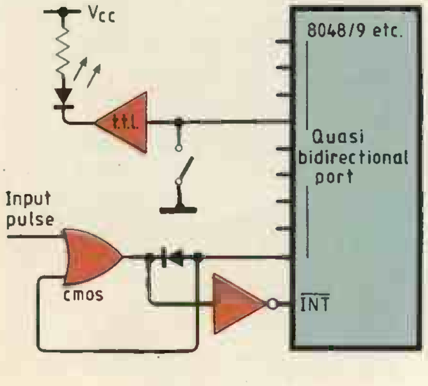
Occasionally when designing with 8048 processors it is useful to have a led indicating the position of a switch connected to one of the i/o port lines. The upper connection in the diagram takes only one line of a quasi-bidirectional open-drain port to do this. Writing a one to the line enables the switch to be read whereas writing a zero or closing the switch turns on the led (the open-drain ports have internal pull-up resistors).

Connecting an Or gate and inverter allows short pulses to reliably cause an interrupt on level-activated interrupt inputs. The gates form a latch that is enabled by writing a one to the port line and which is set by an input pulse. Writing a zero to the port line clears the latch.

Multiple interrupts can be sensed by Oring several such circuits together so that the input, or inputs, causing the interrupt can be read, cleared and enabled through the corresponding port line. If, for instance, the pulsed input is the strobe signal from a parallel printer interface then the output of the Or gate can be used as the busy signal under software control.

By adding external pull-up resistors, these circuits can also be used with open-collector and three-state ports. Three-state outputs should be left floating instead of having a one written to them.

Paulo R. Prondzynski
Porto Alegre, Brazil



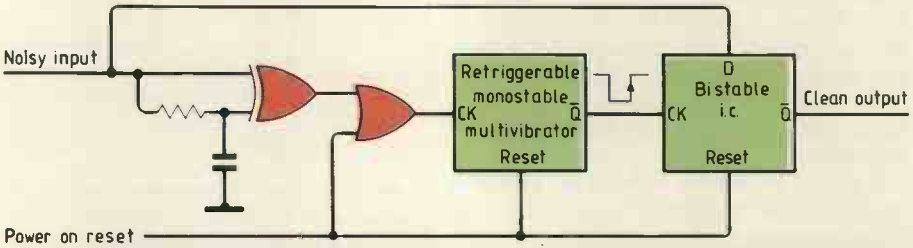
Digital signal cleaner

Unlike the glitch filter published in last year's November issue, this signal cleaner removes spikes, noise and brief level transitions without altering the pulse width or period of the original signal. Clocking and periodic resets are not needed.

An exclusive-Or gate, resistor and capacitor trigger the monostable multivibrator on both positive and negative-going edges of the input signal. After t_f, the monostable i.c. delay, the signal is latched into the bistable device. Since the signal is latched after t_f, any pulses or changes on the input of less than t_f are ignored, giving a clean signal.

Power-on resetting ensures that the output corresponds to the input immediately after power on.

S. Murugesan
ISRO Satellite Centre
Bangalore
India



Proportional mains control interface

Low component count is the main advantage of this proportional mains controller for connection to a computer. Its resolution is only four bits, but 4089 binary rate multipliers can be cascaded to increase resolution.

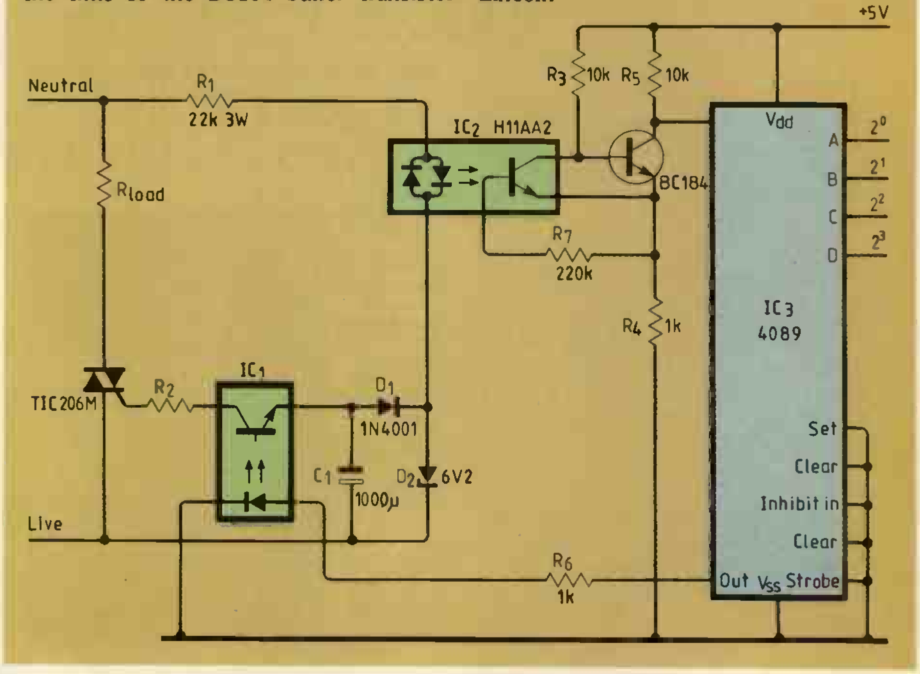
Half cycles during which the controller supplies power to the load are evenly spaced throughout the 16 half-cycle frame. The disadvantage is that at half power the load is driven on alternate half cycles, which is the equivalent of half-wave rectification, so the controller cannot be used with transformer-coupled loads.

Apart from when mains voltage is close to zero, the transistor of isolator IC_1 is on all the time so the BC184 buffer transistor produces a series of short negative-going pulses at 10ms intervals corresponding to the mains zero-crossings.

Crossing pulses from the BC184 clock the rate multiplier which produces n trigger pulses in a frame of 16; n is the four-bit binary value at the multiplier input pins. These trigger pulses feed the triac through the second isolator so the triac is on for n cycles out of 16.

Having the 5V triac-trigger supply ($D_{1,2}$ and C_1) in series with IC_1 avoids using more than one power resistor.

Ian Benton
Sonolux
Lincoln



CIRCUIT IDEAS

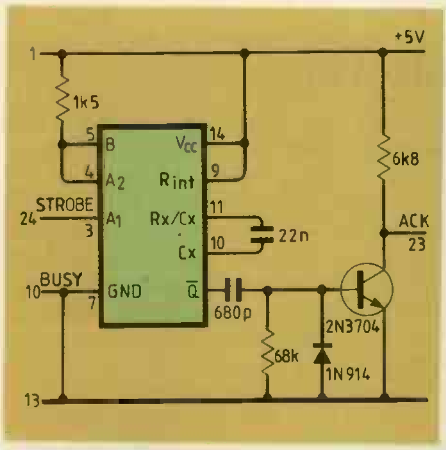
Printer simulator

When attempting to feed a non-existent Centronics-interface printer, some microcomputers enter a continuous loop, waiting for the printer's acknowledge signal. Adding a simple simulator gets round this problem, and allows the printer port to be tested with an oscilloscope or logic probe without having to connect a printer.

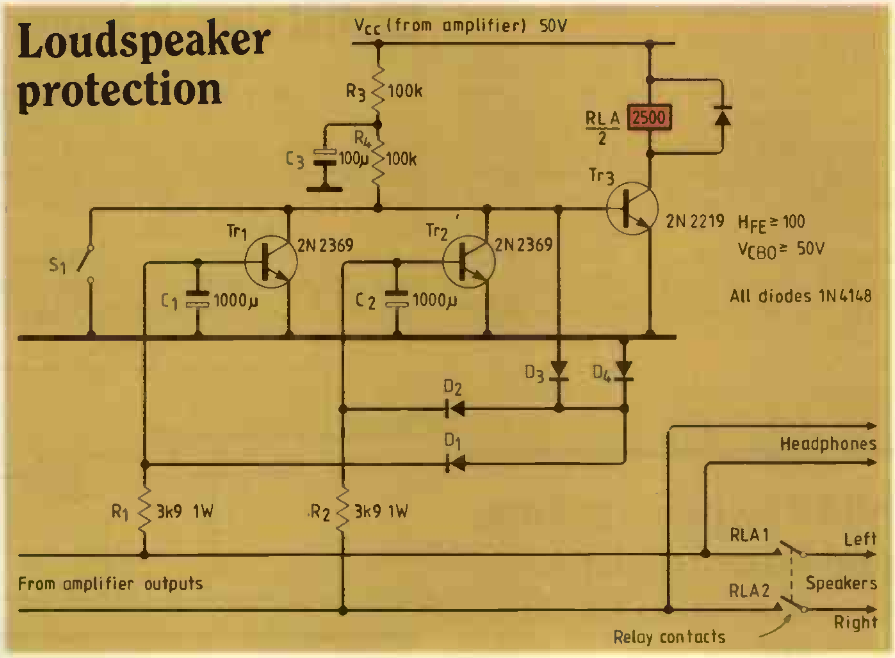
Holding the BUSY line permanently low makes the computer think that a printer is connected. Active-low DATA STROBE signals then trigger a monostable multivibrator whose Q output is normally high, but goes low for about 25μs when triggered. The positive edge of this pulse causes a brief negative-going ACK pulse at the transistor collector.

It should be possible to build the circuit into a D-connector cover.

John Errington
Newcastle-upon-Tyne Polytechnic



Loudspeaker protection



Some faults in modern high-power amplifiers can cause a large direct-voltage output, leading to loudspeaker damage. Three transistors and a relay provide simple and reliable protection with the bonus of a speaker-mute facility.

Normally, left-hand channel output is integrated by R_1 and C_1, greatly attenuating audio frequencies and preventing conduction of either D_1 or Tr_1. Positive d.c. however causes conduction of Tr_1 and negative d.c. causes conduction of $D_{1,3}$. Both of these conditions divert current from Tr_3 and the relay opens. Diode D_4 acts as a clamp, preventing excessive negative voltage from causing emitter-base breakdown. Components R_2, C_2, Tr_2 and D_2 provide similar protection for the right-hand channel.

Maximum voltages across $C_{1,2}$ are +0.6V and −1.2V; a few tests indicated that modern electrolytic capacitors exhibit virtually no leakage under reversed polarity at these voltages. Capacitor C_3 is included to provide a brief turn-on delay to mask switch-on transients. If the transient persists, the circuit holds the relay open until it has decayed. Switch S_1 allows the relay to be opened manually for headphone listening and testing the integrity of Tr_3.

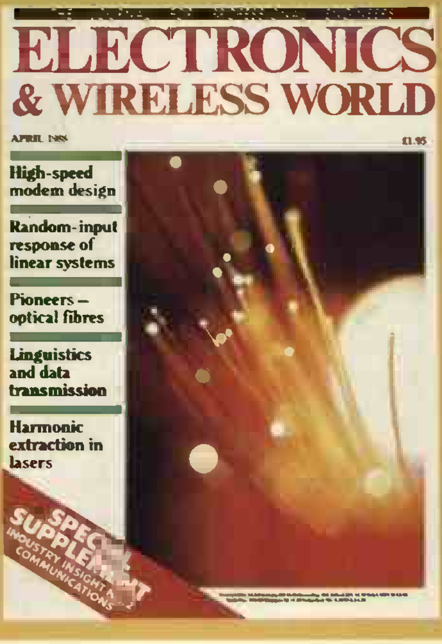
J.N. Wells
St Albans
Hertfordshire

NEXT MONTH

High-speed modem. Kevin Kirk of Anglo Computers describes the operation of a modern high-speed modem and illustrates his description with a practical design for an intelligent, Hayes-compatible modem for the V.22/V.22bis standards

The observer in science. In modern thinking, the observer is not a separate, detached "object", seeing nature from the outside. His presence modifies natural processes and the feedback loops which control his actions pass through the outside world. The dualism of observer and observed is therefore no more. Tom Ivall discusses the idea.

Industry Insight. The second in our new series of commentaries on selected areas of the electronics industry focusses on communications – both voice and data.



Random inputs to linear systems. Howard Hutchings describes how random signals may be modelled and processed by a linear signal processor in the time and frequency domains. Applications of autocorrelation and cross-correlation are included.

Pioneers – Charles Kao. In 1964, Kao addressed the British Association, speculating on the possibility of using glass fibres and light for communications. When serious development started in 1966, attenuation in the available fibres was 1000dB/km.

The seven-per-cent rule. Ivor Catt has investigated what appears to be a previously unknown rule of linguistics, which could have repercussions in data transmission and the size of memories.

FEEDBACK

Atomic fission

I feel I must write with regard to what must be science fiction (Electromagnetically induced atomic fission) in your January issue. There are, I feel, a few comments which should be made.

The claim half-way down p.16 that the electron and proton both appear to have the same physical diameter and no discernible internal structure is not correct. Although classical e.m. theory gives an estimate of electron and proton radius as approximately 2.8×10^{-15}m, experiments have failed to determine a size for the electron, an upper bound on size being set by current machine limitation at 10^{-18}m. The proton, however, can be considered to be 10^{-15}m across, but unlike the electron, does show internal structure.

The first hint of this structure came with the identification of the delta resonance at Brookhaven National Laboratory in the US in 1953 and marked the start of what became very strong evidence that protons consist of more fundamental particles now called quarks.

In the light of this, the suggestion that the "ether" can only withstand a finite electric field intensity equal to that which exists at the surface of Carl Adams' equally sized electron and proton is baseless, as the two particles do, in fact, have drastically different sizes.

The claim half-way down column 1 of p17 that the strong interaction was never observed or measured is also incorrect. Particle scattering studies have determined both that it exists and that it is some two orders of magnitude stronger than the longer range Coulomb interaction.

Finally, consider the frequency of a source of e.m. radiation capable of inducing fission. The critical energy of fission for uranium isotopes is around 5.5MeV. To approach this electromagnetically would require a gamma-ray "laser" to pump the nucleus into fission. Considering the difficulty of secrecy associated with the development of the X-ray laser for the SDI programme, I would enjoy reading a detailed article on Carl Adams' "precisely tuned and oriented e.m. wave" generator to achieve fission, since this device alone is clearly at the forefront of technology.

D. Hankey
Crewe
Cheshire

Carl Adams' January article on 'Electromagnetically induced Atomic Fission' is ahead of its time: – by just three months! Filling in some of the numerical details which he felt might be too complex for EWW readers, nuclei from actinium to uranium and beyond show systematic shape oscillations with excitation energies of some 40 keV, corresponding to frequencies of some 10^{10}GHz, well beyond the range of familiar sources of electromagnetic radiation. The wavelength of radiation of this frequency is about 3×10^{-11}m, or some 3000 times the nuclear radius, so that one has all the difficulties normally associated with using a receiving aerial array (the nucleus) whose linear dimensions are much smaller than the wavelength of the exciting radiation. Such oscillations can however be excited by a pulse of electromagnetic radiation, provided by a close (but not too close) encounter with a proton or alpha particle with an energy of a few MeV. Afterwards all these nuclei, even those which can undergo spontaneous fission, simply re-emit the radiation within a fraction of a microsecond of absorbing it. If Mr Adams hopes to speed up the decay of a lighter radioactive nucleus the problems become even more daunting.

Resonance excitation of nuclei by electromagnetic radiation has been observed, and Mössbauer's explanation of the unexpectedly large yields from Fe-57 won him a Nobel prize, but once again the nucleus which has absorbed the radiation simply waits for a while and then spits it out again. However the Prize categories may yet be extended to include Science Fiction.

C.F. Coleman
Grove
Oxfordshire

Relativity and engineering

As a professional engineer, I enjoy reading the articles and correspondence you publish which express unconventional views on relativity theory and on other aspects of physics in general. Yours is the only publication prepared to offer a forum for such "non-conformist" views, and while most of the contributions contain fallacious arguments, they nevertheless serve a thought-provoking as well as an entertaining purpose. I hope you will continue with this policy.

However, lest any of your readers may have been misled into believing that the Special Theory of Relativity is erroneous and only survives through an Establishment "cover-up", it should perhaps be pointed out that the formulae of the Lorentz Transformation are in regular use by engineers who design equipment involving high particle velocities. The fact that application of these formulae results in equipments that actually function as intended may not constitute an adequate "proof" for philosophers, but it is good enough for practical engineers who earn their living in these fields.

Examples of equipment whose design in influenced by the relativistic increase in mass of a fast-moving particle include high-power klystrons, travelling-wave tubes, microwave gyrotrons, particle accelerators for medical and other uses, and free-electron lasers. These devices all involve the dynamics of fast-moving particles (usually electrons) in their interactions with the electric and magnetic fields of beam-focussing and trajectory-management arrangements, and it is therefore essential to use the relativistic correction to particle mass if the design is to be successful. That the devices in question need not be particularly exotic can be appreciated by noting that even the common-place colour television tube, operating at 25 kV, accelerates electrons to about 30% of the speed of light. This results in a relativistic mass increase of about 5% – an increase which is entirely "real" to a practical engineer.

An even more striking demonstration of the engineering reality of Relativity – and one which I believe will have particular appeal to many of your readers – is provided by the NAVSTAR satellite navigation system. Very briefly, this system comprises 18 satellites in nearly-circular inclined orbits whose radii is about 27,000 kilometres and whose orbital period is 12 hours. Each satellite carries a highly-accurate atomic clock and broadcasts digitally-coded time signals on carrier frequencies of 1,575 and 1,228 MHz; four satellites are normally "visible" from any terrestrial location at any time. The terrestrial platform (ship, aircraft, etc.) carries a receiving system which is "locked-on" to the four visible satellites, and which measures the arrival time of each of their four time signals with respect to its own, not so accurate, clock. These four time-delay measurements are combined with ephemeris data (also broadcast by the satellites) to set up four simultaneous equations in four unknowns, which are solved by the receiving system's computer. The resulting outputs are the platform's position in three dimensions (latitude, longitude, and height) together with the necessary correction to the receiver clock to re-align it to satellite time. Positional accuracy has been quoted as 18 metres r.m.s., and time accuracy as 35 nanoseconds.

FEEDBACK

The achievement of this remarkable degree of accuracy required the system designers to take due account of relativistic time-dilation arising from a satellite's orbital velocity of about 4 km/s. Small though the effect is, it results in the satellite's clock losing about 350 nanoseconds per hour, which corresponds to a build-up of positional error of the order of 100 metres per hour. In order to compensate for this effect, the satellite's clock would have to be set before launch to run 350 nanoseconds per hour fast with respect to standard time.

However, there is also an even more important effect; General Relativity predicts that clocks run more slowly in a gravitational field. Since the satellite is 27,000 km from the centre of the Earth, whereas the Earth's surface is only 6,400 km away, the satellite is in a weaker gravitational field and its clock therefore runs *faster* than it did prior to launch. The two effects are therefore in opposite directions, but General Relativity predominates in this particular case, and calculation shows that the net effect is that the satellite clock runs fast to an extent that would result in an error growing at a rate of about 500 metres per hour. The atomic clock is therefore deliberately built to run slow by the amount calculated by the relativistic formulae, so that it keeps correct time after the satellite is positioned in its orbit.

It can therefore be seen that although there may still be scope for deeper philosophical debate, Relativity is now firmly established in engineering as a practical design tool.

J.C.G. Field
Bath
Avon

Recent articles in *EEW* have sought to undermine the foundations of Special Relativity by seeking some error in the mathematical reasoning upon which it is based. As was pointed out by Harald Nordensen, many years ago, the epistemological basis for Einstein's theories is unsound and contains the unconscious acceptance of classical time in its attempts to prove the necessity for a new definition.

There is, however, a further reason to doubt the soundness of Einstein's model, and it may be illustrated by the following thought experiment.

A relativistic physicist decides to test the theory of Special Relativity by sending a clock to Alpha Centauri and back. This will, he assures his acolytes, finally prove the case for the slowing of time under accelerated conditions. It will be a simple matter to compare the elapsed time shown on the returned clock with the time kept in our Galilean locality. As he recognises the importance of accuracy to the success of the experiment, he approaches the best horologist in the world and commissions him to manufacture a timekeeper equal to the task.

The horologist agrees but, as he has little faith in the prognostications of mathematical physicists, he decides to make a timekeeper that will be immune to the effects of relativistic junketing. He has read 'Relativity' and is well aware of the prediction by Einstein, that as the clock's velocity increases, the mass of its balance wheel will also increase.

"If this is so", he reasons, "Then neglecting the second order effects due to the increased mass of the balance spring," (he is a most careful and thorough analyst). "And assuming that the losses in the system are unchanged, being a function of the oscillating systems velocity only, then the amplitude of oscillation must increase. The quality factor of the oscillator, 'Q' is proportional to $\omega M/r$ so that as the mass of the balance increases, the angular velocity will decrease in inverse proportion to the square root of the difference in mass while the Q will increase in direct proportion."

As the amplitude of oscillation increases, he needs a compensating effect to maintain the clock's period constant, therefore, he pins up the balance spring so as to make the balance spring combination faster in the longer arcs. Thus, the increasing spring constant with increasing amplitude will compensate for the increasing mass and the ratio K/M will be kept constant.

The physicist pronounces the clock satisfactory, and with due white coated ceremony it is placed aboard the Alpha Centauri spacecraft, then launched on its way.

Many years later, the spacecraft returns and the now aged physicist, supported by his remaining acolytes, carries the timekeeper in triumph to the laboratory for comparison with the master clocks which throughout this long period, have ticked away with uncompromising accuracy.

To their horror, no difference can be found between the travelled clock and the stay at home master clocks. The shock is too much for the aged master and he expires, leaving the bereft acolytes to discover some explanation.

Some curse the clockmaker as incompetent, others embark on the formulation of a mathematical theory of great complexity and rigour to show that the effect of the clock's journey (including necessary relativistic corrections) over the distance to Alpha Centauri and back is such that the hands of both master and slave exactly coincided on its return. Others busily examine the data pertaining to the master clocks and carefully test their accuracy using the best (and most expensive) test equipment available. Some simply went home to beat their wives. Only the clock was right.

The above parable for our times has a further sting in its tale. Even if Special Relativity were not true, the clock would still have shown no error upon its return, assuming that the horologist had completed his task in a competent manner. If the amplitude of oscillation remained constant, then no rate error would result from the non-linearity of the balance spring and no difference would occur in the result of the experiment.

It is therefore impossible to draw any conclusion concerning the validity or non-validity of Special Relativity from an experiment involving what we like to call 'clocks'.

Let one thing be made absolutely clear, as clear as it was to the horologist whose tweezers manipulated the balance spring to such good effect. Clocks do not measure and cannot measure classical time. What we define as clocks are merely oscillating systems whose periodicity is governed by the Galilean values of the parameters at the epoch of observation. As any clockmaker could have told Einstein, the rate of the clock is subject to the influence of the non-linearities inherent in its operation. What Einstein demonstrated was that he had little understanding of how a clock actually functioned.

Otherwise, I shall be forced to assume that relativistic effects are occurring between the lounge and kitchen in my home as, in common with the houses of most other horologists, none of the clocks therein show the same time! I make no excuse for the choice of a balance wheel timekeeper in the above thought experiment; in this I merely follow Einstein who did the same. If it is wished to argue that quantum mechanical clocks are somehow different, that some mysterious linkage exists between the functioning of atomic structure and this derived parameter 'time', then the physicist must show that the conditions which were generated by the horologist in the thought clock cannot possibly apply to atomic mechanics. That is, that no non-linearities or hidden variables are possible within Quantum theory. If he persists that such a view is correct I can only refer him to the sound reasoning of Popper on this subject[2].

If he argues that such a system of parametric compensation is

FEEDBACK

impossible or would not function, I shall direct his attention to the Gurney clock in Norwich which was built by Martin Burgess, using the ideas of John Harrison, the 18th century clockmaker.

Harrison's investigations into the stability of timekeepers led him to the perfection of a nonlinear model for a clock oscillator with parametric compensation.

There is little evidence in physics that the subjective parameter, 'time' has any importance to the universe. What we call 'time' is the product of our cognitive perception and is governed by the 'clock' inside our heads. It is perhaps, a product of our arrogance that we have chosen that particular facet of our abilities, which set our hominid ancestors apart from all other species on this planet, as a universal governor for the whole cosmos. It was short term cognitive time perception that made Koestler's primaeval man "shudder and see omens at every step."

It will be noticed that the above experiment in no way conflicts with our concepts of causality, although it does have grave consequences for probabilistic theories based on linear algebra. It is closer to Popper's propensity dynamic which allows system behaviour to be influenced by parametic structure.

In that context, if Harrison's ideas had been understood in his lifetime, if the functioning of non-linear systems had been recognised by 19th century physicists as vitally important, then the muddle and misunderstanding described by Popper need never have come about.

References

1. Relativity, Time and Reality – H. Nordensen. Allen and Unwin, 1969.
2. Quantum Mechanics and the Schism in Physic – Karl R. Popper. Hutchinson, 1982.

Mervyn K. Hobden
Lincoln

Catt's anomaly:

It seems that Dr Catt has once again set up his own version of conventional theory in order to debunk it. Catt's anomaly (*EEW* Sept. 87. p903) isn't, as I will explain. Practical people like myself prefer concrete examples, so I will begin by putting dimensions to his Fig.7. My Fig.1 shows the same strip line with copper conductors 1mm apart, but 1m deep into the paper in order that we can ignore "edge effects": this doesn't matter – you can repeat the sums for narrow strips afterwards with edge effects, or you can use algebraic dimensions, but it will not change the conclusions.

I shall assume a t.e.m. step travelling to the right as he does, and make it 5 volts high. The electric field E is then 5,000 V/m, and the flux density D, or surface change density on the conductor, whichever you like to call it is:

$$D = \epsilon_0 E = 5{,}000 \times 8.854 \times 10^{-12} \text{coul/m}^2$$
$$=2{,}763 \times 10^{11} \text{electrons/m}^2$$

I have, of course, used the fact that each electron carries a charge of 1.6×10^{-19} coulombs. As the t.e.m. step is travelling at the speed of light, the next metre of strip must gain this same charge in 3.33ns (yes, I agree, 1ft/ns is nicer). Where, Dr Catt asks, do these electrons come from? The answer is that they are already there: copper atoms are 2.28×10^{-10} metres apart (I worked this out from my 0-level chemistry book). According to the conventional theory I was taught, each copper atom contributes one electron to the conduction flow, leaving itself positively charged by the same amount. Before the t.e.m. step arrives, the density of positively charged copper atoms and the electrons they have contributed is the same, so there is no net electric field. Assuming that the copper atoms are arranged on the surface in a square grid, this density is

$$(1/2.28 \times 10^{-10})^2=1.92 \times 10^{19} \text{ electrons/m}^2.$$

This is so huge that we need only increase the existing surface density by 1 part in 70 million in the next 3.3ns to achieve our aims. This will happen if all the electrons in the surface move up a little bit, as shown in my Fig.2. In other words, all the electrons must start travelling to the right, immediately the t.e.m. wave passes them, at 1/70,000,000 of the velocity of light, i.e. about 4 m/s. An electric field so high as to cause flashover would involve a difference from neutrality of only 1 electron in 200,000 surface atoms, so we are never likely to run into trouble with conventional theory.

It is actually better than this, because whoever heard of a strip line one atom thick? If we make the line 0.01mm thick (my Fig. 3), i.e. about 44,000 atoms thick, the average electron drift velocity required is 44,000 times smaller, or about 10^{-4} m/sec, which is what I was taught to expect. Lest anyone point out that current flow in the surface "at these frequencies", I have already dealt with that, since even 4m/s is much less than an electron's velocity. Behind the step, the currents is of course d.c., so one can imagine a transition from the regime of Fig.2 to that of Fig.3. I find the above conventional theory intuitively obvious. Your readers will have to judge whose intuition is best.

I do not wish, in my turn, to debunk Dr Catt's theories; indeed I was designing capacitors for thermonuclear experiments using transmission line theory in 1958, because it seemed the only sensible approach. But it didn't lead me to lose my faith in displacement current: quite the opposite! If you read carefully Drs Catt and Watson's earlier papers in *WW* you will find they contain a mathematical howler, as a result of which displacement current isn't debunked after all. Don't ask me what this howler is; along with many of my colleagues, I find this correspondence very entertaining, and I wouldn't like it to stop. but I will give you a clue. Whenever Dr Catt debunks conventional theory he insists on using a perfect mathematical step. Can you differentiate at a step? Have you ever seen a step? With modern oscilloscopes they always turn out to be ramps.

John Matthews
Exeter

Fig. 3

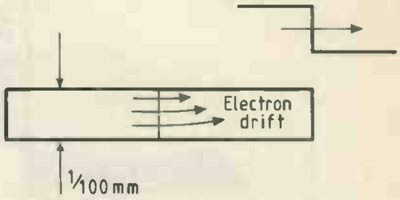


Fig. 1

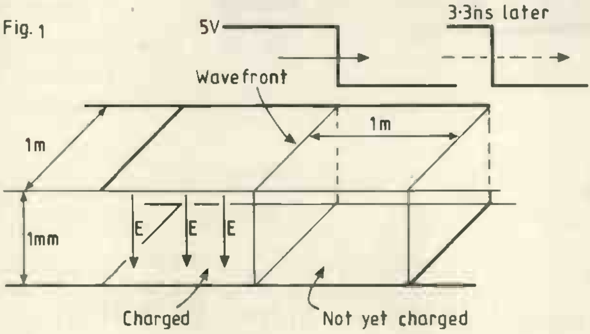
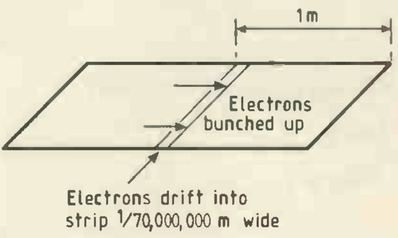


Fig. 2



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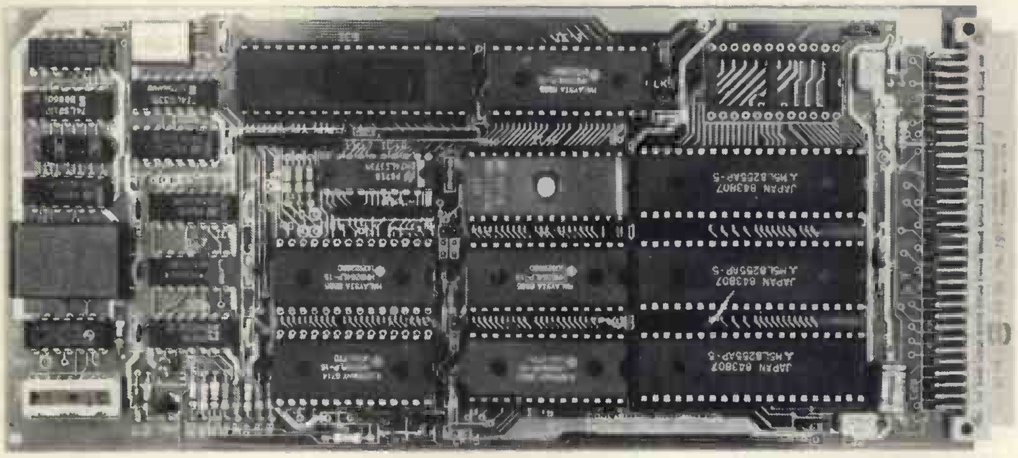

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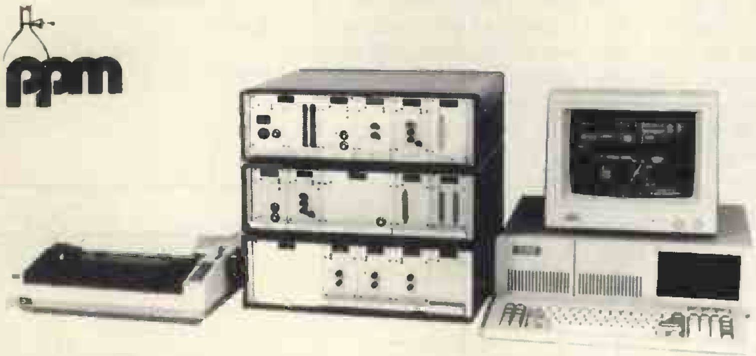

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It has been said – usually by journalists facing a deadline thirty minutes away with not an idea in sight – that there is nothing quite so hostile as a blank sheet of paper; even putting the date at the top of the page rarely seems to be very stimulating.

Nevertheless, to judge from the number of letters that come into this office, our readers do not suffer badly from mental blocks of this kind and, on the whole, tend towards the verbose. Encouraged by this tendency, we have decided to run a competition during 1988 with the aim of extracting readers' views on the way forward in engineering research and development. The leader on page 219 poses one or two questions that might be addressed, but there is no need to feel inhibited about raising your own and offering solutions.

Bear in mind that engineering is international: narrow, nationalist politics are, of course, important but the aim of the competition is to elicit opinion on the larger question of the direction in which international effort in electronics might most usefully be directed.

Our intention is to publish a selection of the best essays, so that the length should not exceed about 4500 words, or three printed pages in *EWW*. Diagrams can be used if necessary, but the space they occupy will have to be deducted from the 4500 words.

The judging panel will be composed of respected names, both in and outside industry and the prize-giving ceremony will be in London.

NEC Electronics (UK) Limited have joined *EWW* in sponsoring the competition and have provided the first three prizes.

This is the first announcement of the competition to enable readers to begin the thinking process – the writing is the easy bit! There will be several months during which to marshal your thoughts and we will give more information in the next few issues.

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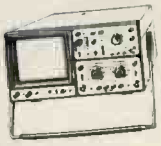

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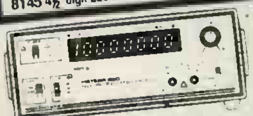

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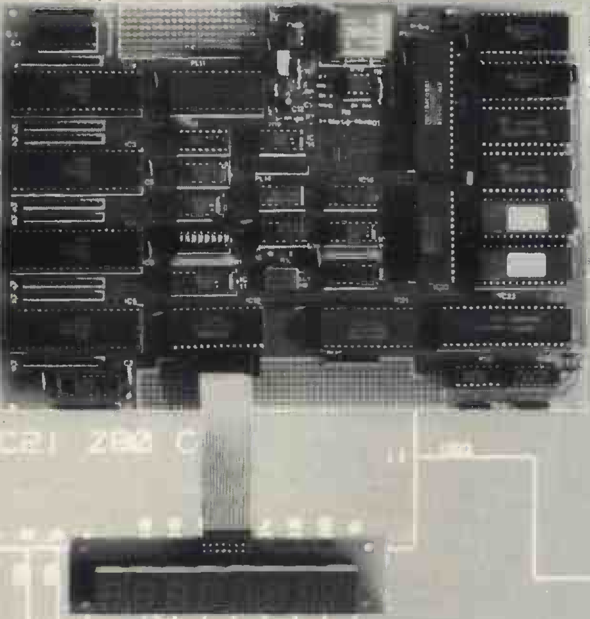


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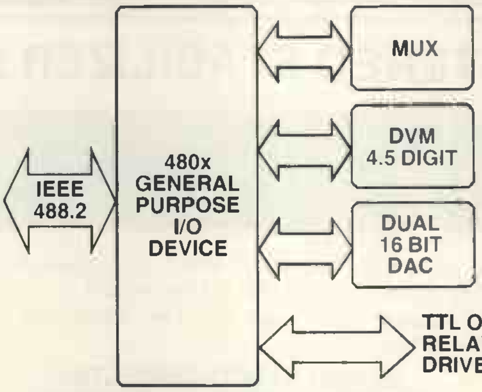
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4GHz synthesized local oscillator design

The local oscillator of a spectrum analyser plays a vital part in the overall performance. This article describes the design of a microwave synthesizer.

IAN BRAITHWAITE

Fig.1. Marconi Instruments 100Hz – 4.2GHz 2383 spectrum analyzer incorporates a precision frequency synthesizer.

The radio-frequency spectrum analyser, like its relative the communications receiver, has to meet ever more demanding requirements as communication technology advances. The signals to be analysed can cover a very large range of amplitudes (dynamic range), and be closely-spaced in frequency, making it difficult to resolve the individual spectral components. Accuracy and resolution is essential to make high quality measurements. The analyser's local oscillator system is crucial to obtaining good resolution, and forms the subject of this article. Some of the design considerations and building blocks are reviewed, with a high performance 100Hz – 4.2GHz spectrum analyser (Fig.1) used as an example of a practical design.

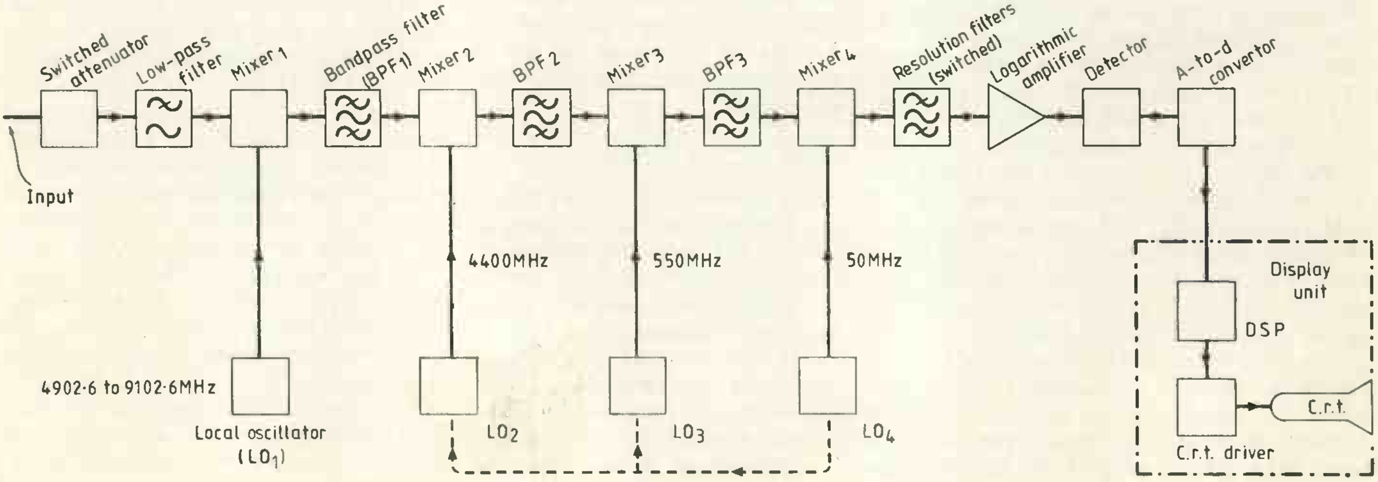
SPECTRUM ANALYSER SYSTEM

A greatly-simplified block diagram of the spectrum analyser is shown in Fig.2. Similar to the broadband communications receiver, it is based on the superheterodyne principle, using a number of frequency conversions. An electromechanically switched, resistive attenuator keeps the input signal level into mixer 1 such that the mixer generates very little distortion. Mixer 1 is used as an up-convertor, with the first local oscillator tuning above the input band of 100Hz to 4.2GHz to give a constant intermediate frequency of 4.9GHz. This allows the image band of mixer 1 (where the image frequency is the sum of the l.o. and i.f. rather than the difference) to be rejected by a low-pass filter which does not require tuning. The first i.f. is selected by a bandpass filter which must reject the image frequency of the second mixer. Because the selectivity of any bandpass filter is limited, frequency conversion down to the final i.f., where the bulk of the gain and filtering can be applied, has to be done in stages, with each down-converting mixer producing an i.f which is approximately ten times lower in frequency than its input signal.

One major difference from the communications receiver is the need to sweep the first l.o., so that a wide range of input frequencies can pass through the resolution filters. All the other local oscillators are fixed in frequency, the 550MHz and 4.4GHz sources being derived by multiplication from a 50MHz low-noise crystal oscillator.

The resolution filters, as their name suggests, give the instrument its fine spectral resolution, and considerable effort has been expended in the development to provide state-of-the-art filtering down to 3Hz (−3dB) bandwidth so that even low-level 50

Fig.2 Simplified spectrum analyser block diagram.



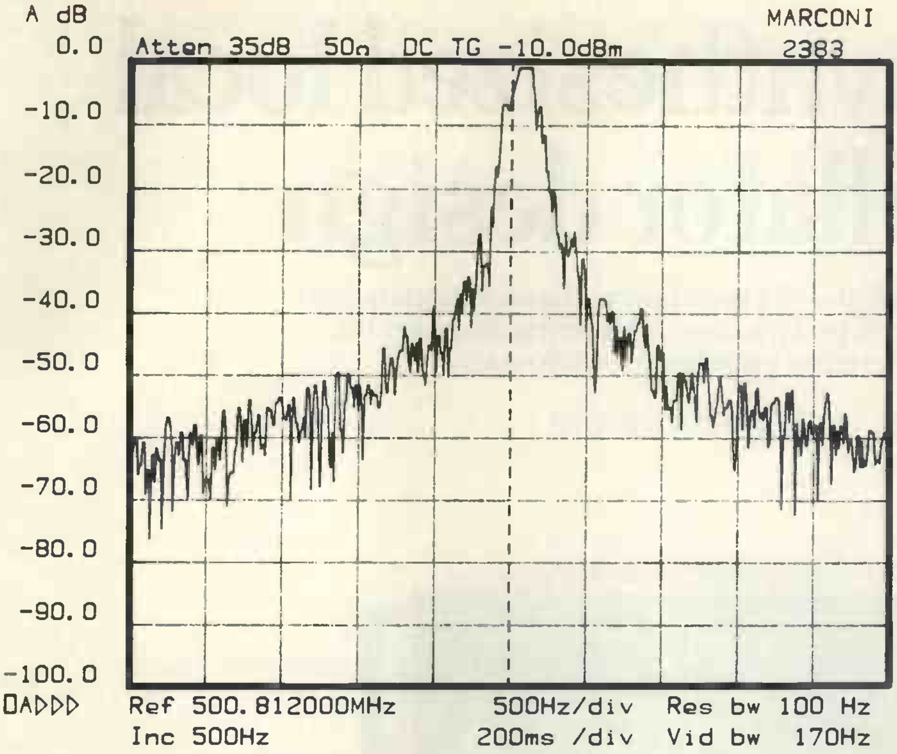


Fig.3. **Effect of frequency jitter.**

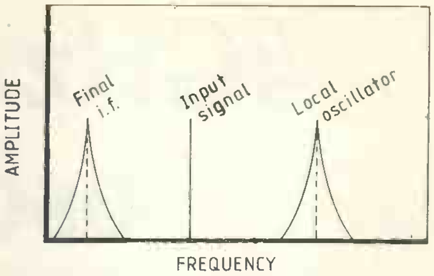


Fig.4. **Noise on a receiver local oscillator is translated on to the final i.f. (reciprocal mixing).**

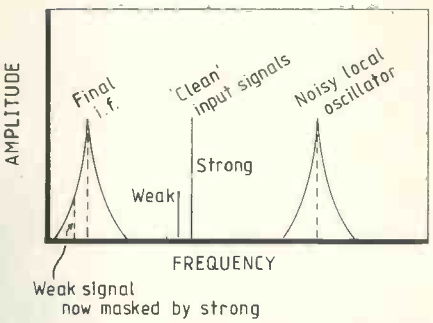


Fig.5. **Reciprocal mixing by a strong signal can mask a weak signal, limiting resolution.**

or 60Hz hum sidebands can be resolved.

Following filtering, the signal is routed through a logarithmic amplifier to give a vertical scale calibrated in dB. Analogue-to-digital conversion then takes place and the information is sent to the display unit as a serial data stream for processing, which entails averaging, error-correction, peak detection and conversion to a form suitable for feeding the cathode-ray tube display.

EFFECT OF THE LOCAL OSCILLATORS

The benefit to be gained from narrow-resolution filters will never be realised unless the local oscillator system is correspondingly good. This is because any drift or angle modulation (frequency or phase) by coherent signals or noise on the local oscillators is transferred directly by the mixing process on to any signal in the i.f. system, and cannot then be distinguished from defects in the input signal itself. This effect is known as reciprocal mixing. Thermal drift and low-frequency jitter on the oscillators will distort the filter response shape, as Fig.3 shows. Coherent sidebands add apparent signals or mask those present on the input signal. For instance, it is of little use attempting to measure the level of mains sidebands on the input signal of around −50dB relative to the carrier (i.e. −50dBc), if the local oscillators have such sidebands at −30dBc.

Angle modulation of the oscillators by white noise or flicker noise, usually referred to as phase or sideband noise, limits the resolution attainable. (Flicker noise is also called 1/f noise because its amount is inversely proportional to frequency.) Such modulation occurs in the oscillators themselves and may be due to noise in the oscillator or its driving circuitry, the net result being a broadening of the spectral line, as shown in Fig.4. As Fig.5 shows, the sideband noise imposed on a strong signal by the instrument's oscillators can mask a weak signal which would otherwise be resolvable.

Achieving a good oscillator performance in a spectrum analyser covering up to several gigahertz is made difficult by a number of factors. The first and second l.os work above the highest input frequency, whereas some of the sources which have to be measured will be at low frequencies. As the frequency of an oscillator rises so the drift, jitter and sideband noise tend also to rise. Secondly, the first l.o. has to be swept over nearly an octave. This makes it very susceptible to external noise on its tuning input; and thirdly, there are a number of oscillators which can all degrade overall instrument performance.

As all oscillators but the first are fixed, and can be derived by multiplication from a low-noise, high-stability source, it is the first l.o. which tends to be most critical. The design of the swept first l.o. will be studied. This is a frequency synthesizer with low drift and jitter, giving good close-to-carrier resolution and frequency accuracy. Some frequency synthesizer techniques will first be reviewed in order to clarify some of the detail of the actual design.

FREQUENCY SYNTHESIS

In frequency synthesis, the ultimate output frequency is a combination of other frequencies. Phase-locked loops are commonly, though not exclusively, used to perform frequency manipulations, since they act, in effect, as narrow-bandwidth filters. Figure 6 illustrates a number of different types of basic loops. In (a), the phase of a voltage-controlled oscillator is compared in a phase detector (also commonly called phase comparator, or phase-sensitive detector) with a reference signal. The phase detector output is filtered, the filter defining the loop's bandwidth, and the filtered voltage then tunes the v.c.o. The action of the negative-feedback loop is to steer the v.c.o. until it bears a fixed phase relationship to the reference signal, so that the phase detector's input frequencies are equal, a common feature of all phase-locked loops. In this loop, the v.c.o. frequency equals the reference frequency. The loop filter can be designed, if need be, to reject coherent signals and noise present on the reference. One application for this type of loop is a low-phase-noise crystal oscillator with relatively poor long-term stability, locked to a noisier but more stable timing reference, to obtain the advantages of both, the loop acting as a filter.

In (b), a digital divider has been placed between v.c.o. and phase detector. Since the loop always strives to maintain the phase detector input frequencies equal, the v.c.o. frequency in this case is a multiple of the reference frequency.

In loops where the v.c.o. operates in the gigahertz range, digital dividers become impractical with presently available technology. In (c), the loop reference signal samples the v.c.o. waveform, using very narrow pulses to close the switch for a brief instant. When the switch opens, the sampled voltage is held on a small capacitor. If the same point on the v.c.o. waveform is sampled each time, the sampling gate output will be constant, the voltage depending on the relative phase of the reference and v.c.o. If the sampling point changes, the sampling gate output will be a beat note whose frequency is the difference between the v.c.o. and a harmonic of the reference. The sampling gate operates as a phase detector and the v.c.o. operates on a harmonic of the reference frequency as in

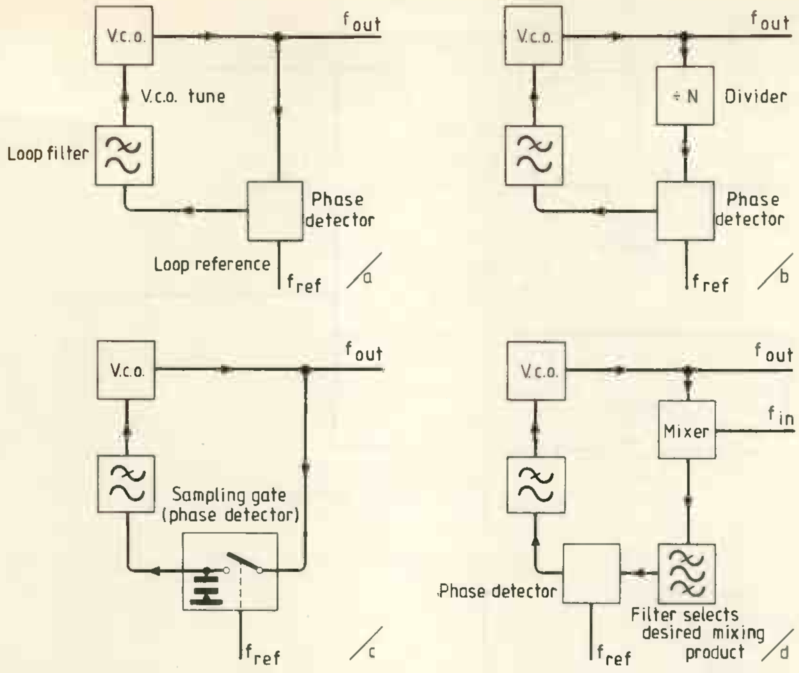
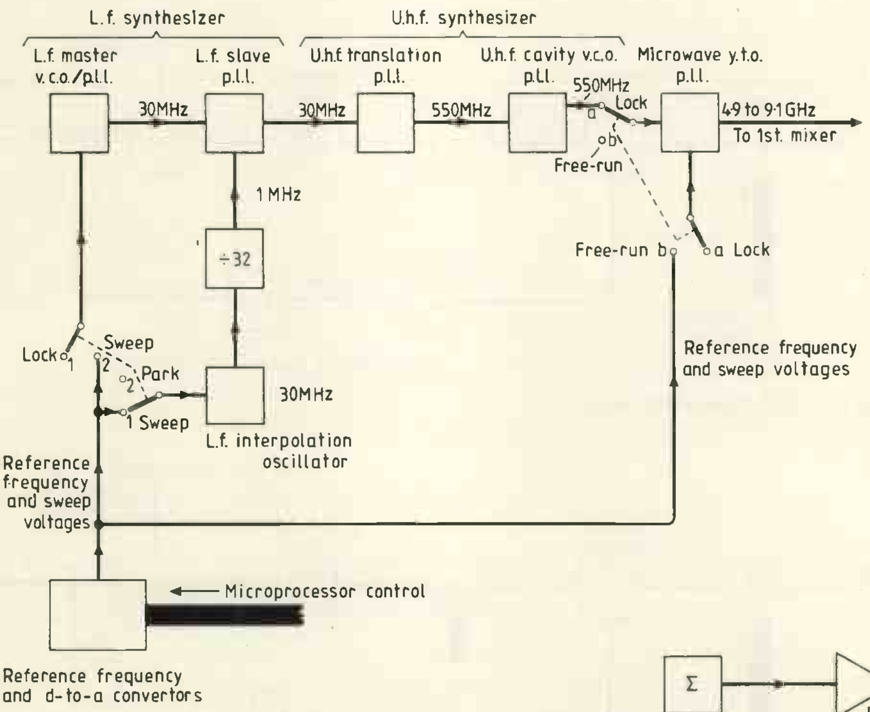


Fig.6. Some types of phase-locked loop.



(b). In (d), a third input frequency has been introduced, which is mixed with the v.c.o. A band-pass filter on the mixer's output selects the wanted mixing product, often the difference frequency, and feeds this to the phase detector. As the diagram shows, this mixer loop gives frequency addition and subtraction.

As we shall see, practical designs of loops may use a combination of the above ideas.

SYNTHESIZED FIRST LOCAL OSCILLATOR

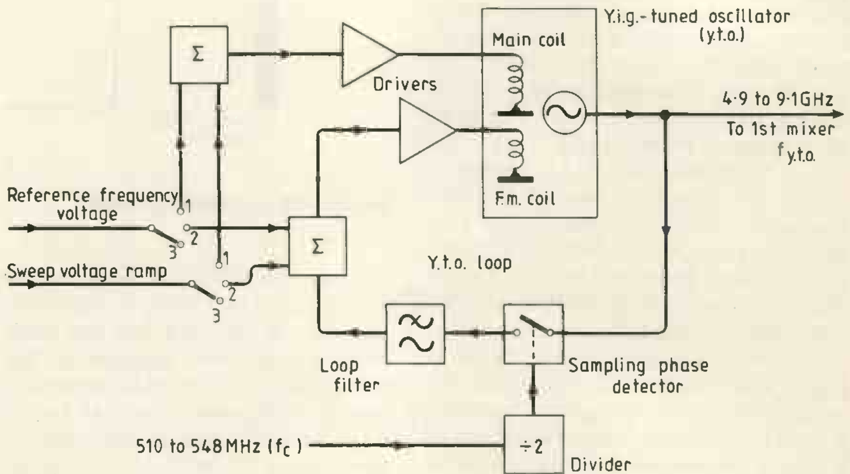
An overall system block diagram is shown in Fig.7, broken down into the various loops. There is always one free-running oscillator which is swept. The actual oscillator which feeds the first mixer is a YIG-tuned oscillator (y.t.o.), the tuned circuit of which is a tiny sphere of yttrium iron garnet whose resonant frequency can be varied by changing the magnetic field in which the sphere sits. The magnetic field is provided by two coils wound on a polepiece, the main coil giving about 20MHz shift for every milliamp of current, and the f.m. coil with a sensitivity of about 300kHz/mA. On the widest spans (100 to 4200MHz) the noise and jitter on the y.t.o. cannot be resolved on the screen, so the y.t.o. itself is simply tuned and swept in a free-running state. The sweep voltage is derived from microprocessor-controlled digital-to-analogue convertors, the voltage being applied to the main coil driver, a voltage-to-current convertor. For spans of 5 to 50MHz, the noise of the main coil driver would be visible, so its bandwidth is reduced and it receives only the reference voltage, the sweep being applied to the f.m. coil driver.

For spans of less than 5MHz the y.t.o. jitter would become noticeable again, so the y.t.o. is phase-locked to a u.h.f. source, a so-called "cavity" v.c.o. using a sampling loop (see Fig.8). The cavity frequency is divided by two to provide extra harmonics so that it only has to cover about 5% tuning range to give continuous cover at the y.t.o. This small tuning range helps to keep noise and jitter low.

The y.t.o. loop contains a search oscillator so that the y.t.o. only has to be steered by the reference voltage to within 50MHz of the correct frequency to acquire phase lock. Frequency relationships in the loop are summarized in the diagram. The cavity v.c.o. itself is always phase-locked, the swept, free-running oscillators being located in the low-frequency synthesizer shown overall, in Fig.7. and in detail in Fig.9. This

Fig.7. Overall simplified block diagram of the synthesized first local oscillator.

Fig.8. The y.i.g.-tuned oscillator (y.t.o.) loop.



Switching :–

Position	Function
1	Sweep main coil (100 MHz to 4·26GHz spans)
2	Sweep f.m. coil (5 to 50MHz spans)
3	Synthesized sweeps (100 Hz to 2 MHz spans)

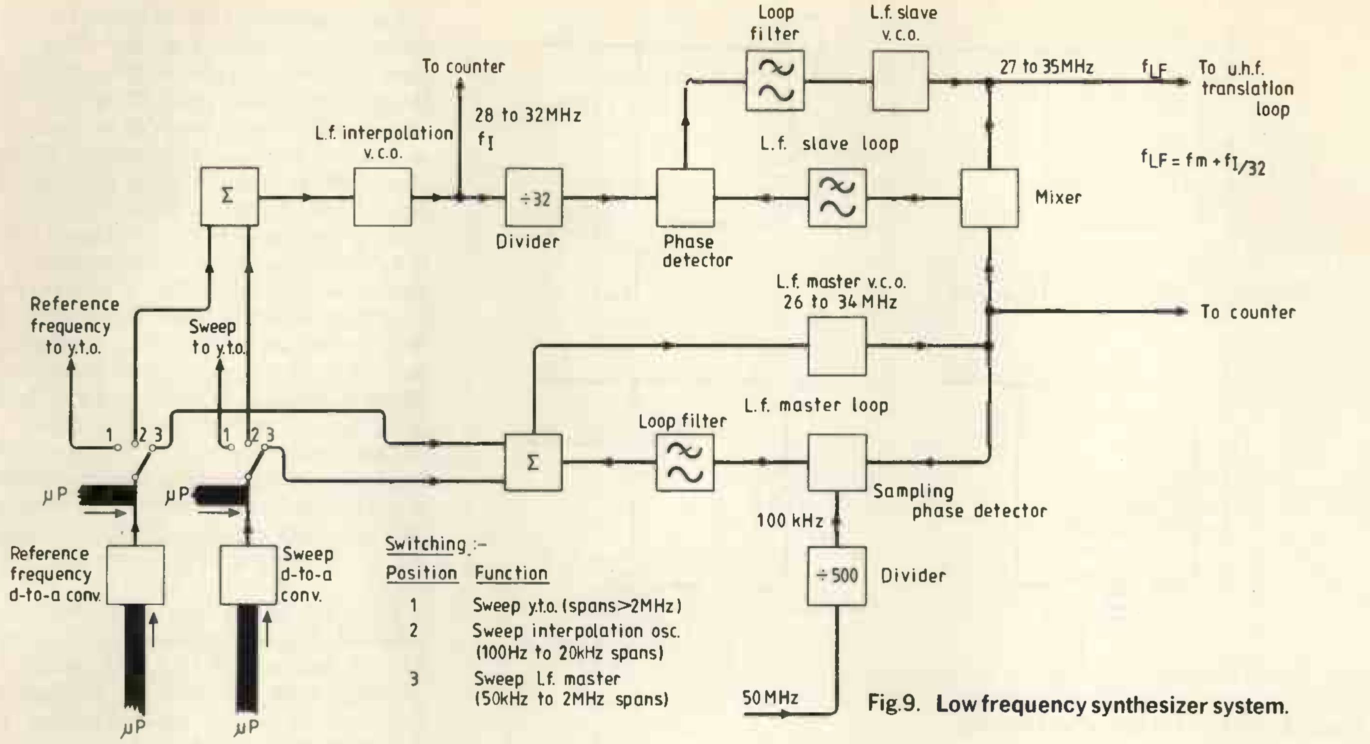


Fig.9. **Low frequency synthesizer system.**

cavity v.c.o. contains two loops: the first is the l.f. master v.c.o. loop, whose v.c.o. can be positioned and swept free-running or phase-locked using a sampling loop in 100kHz steps; the second loop is an l.f. slave which adds the frequency of the l.f. master v.c.o. to that of the l.f.-interpolation v.c.o. (which is never phase-locked) divided by 32.

The l.f. synthesizer is operated in two modes, as indicated in Fig.8. For spans of 50kHz to 2MHz, the l.f. master v.c.o. receives reference and sweep voltages, while the interpolation oscillator is "parked". The overall frequency is established by counting both oscillators. Over spans of 100Hz to 20kHz, the l.f. master is positioned close to the desired harmonic of 100kHz, and phase-locked to the instrument's timing reference. The l.f. interpolation oscillator is now positioned and swept. Again, exact frequency is established by counting. Because of the division by 32, the noise and jitter of the l.f. interpolation v.c.o. and hence the l.f. slave v.c.o. which follows it, is more like that of a 1MHz oscillator, i.e in this context, very low.The u.h.f. synthesizer in Fig.7 transfers the sweeps from the l.f. synthesizer to the u.h.f. range of phase-locking the y.t.o. As can be seen from Fig.10, l.f. synthesizer sweeps are digitally divided by the same harmonic number involved in the y.t.o. loop, then multiplied by four in the translation loop itself. The output from the translation v.c.o. covers 553 to 558MHz, with less than 0.25MHz occupied by sweep.

The cavity v.c.o. loop in Fig.11 carries the sweeps and also provides continuous coverage at the y.t.o., by causing the y.t.o. to step in 10MHz intervals. It uses two dividers; the N divider compensates for harmonic multiplication, so that the smallest change in the m divider causes a 10MHz y.t.o. shift. There are 27 steps to fill in the 270MHz or so gaps between the y.t.o. harmonic lock points.

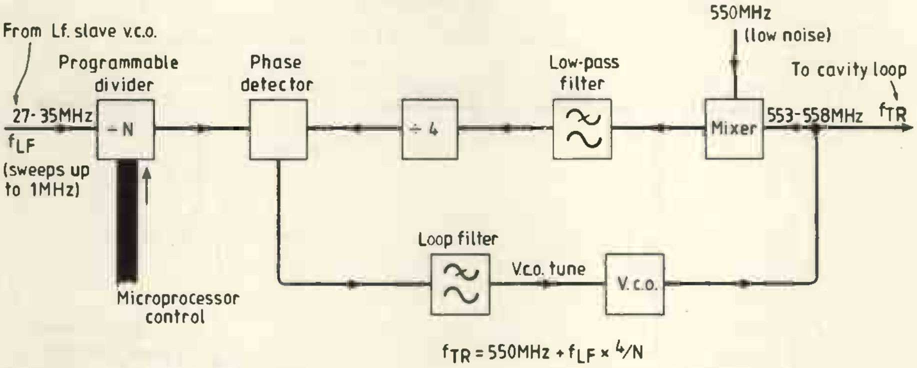


Fig.10. **U.h.f. translation loop.**

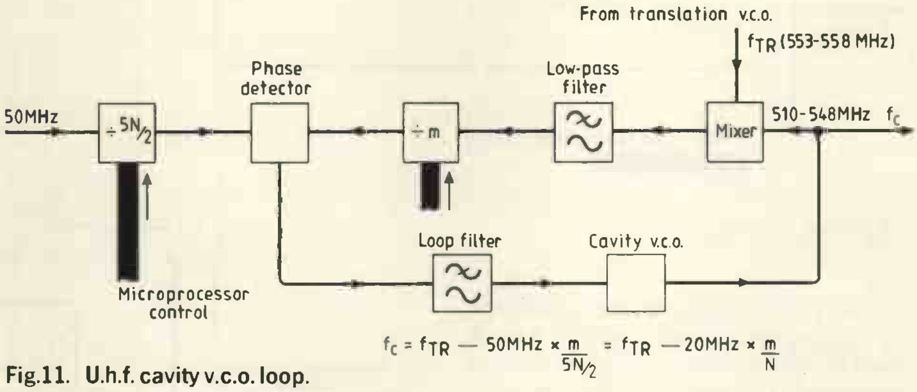


Fig.11. **U.h.f. cavity v.c.o. loop.**

Following through the system, we see that the net multiplication factor of the l.f. synthesizer is two, so the process has forced the y.t.o. to have the drift and jitter of a free-running 2MHz oscillator on the narrowest sweeps (l.f. interpolation oscillator at around 32MHz divided by 32 and multiplied by 2), which is considerably better than a free-running 5 to 9GHz y.t.o.

USE OF THE MICROPROCESSOR

Once a reference frequency and span are selected from the front panel or by remote control via the GPIB, the microprocessor sets the system to the correct mode, depending on the span. If the full synthesizer is required, the cavity oscillator is tuned close to the correct frequency by setting the cavity and translation loop dividers. The y.t.o. is then steered close to the desired frequency and locks to a cavity harmonic (the processor checks for lock) and the reference voltage is removed from the y.t.o. loop and applied to the l.f. master or interpolation oscillator. The correct frequencies are established by an iterative process of steering and counting, and when all is ready, sweeps are applied to the appropriate oscillator. Frequencies are checked at intervals to ensure accuracy.

In order that the system can work at all, the tuning law of most of the oscillators is calibrated using the instrument's special diagnostic and calibration software. As all the hardware is self-contained, this can be done in circumstances of field repair, no other instruments being required.

PERFORMANCE

The resultant performance can be gauged from Figs. 12 and 13. Figure 12 illustrates the instrument's close-to-carrier resolution when measuring a 50MHz crystal oscillator with the 3Hz filter. Note the absence of 50Hz power line sidebands. When tuned to 50MHz, the first local oscillator frequency in the instrument is close to 5GHz. Figure 13 demonstrates the f.m. demodulation mode available in the instrument. The local oscillator is positioned automatically to bring the final i.f. some way down the filter characteristic so that frequency fluctuations are turned into voltage fluctuations (a technique known as slope detection). These are traced out against time, to show frequency deviation against time. Random frequency fluctuations of the combination of the signal source and the analyser's own oscillator are seen, illustrating the considerable stability of the first local oscillator, now operating in the region of 9GHz.

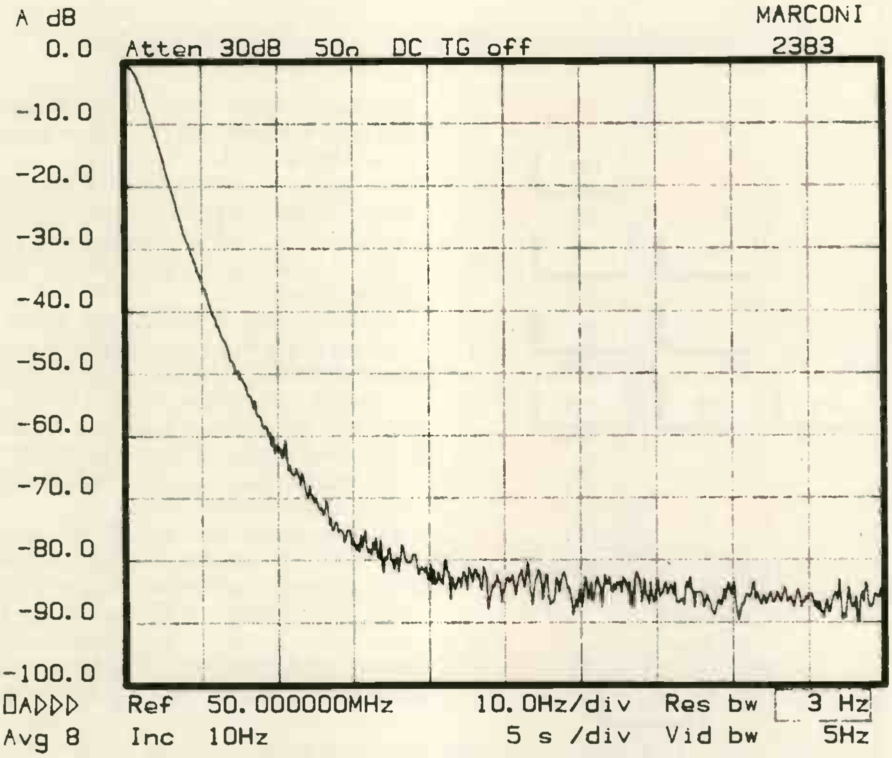


Fig.12. Close-to-carrier resolution of a 50MHz crystal oscillator. Hum sidebands 80dB down can be resolved.

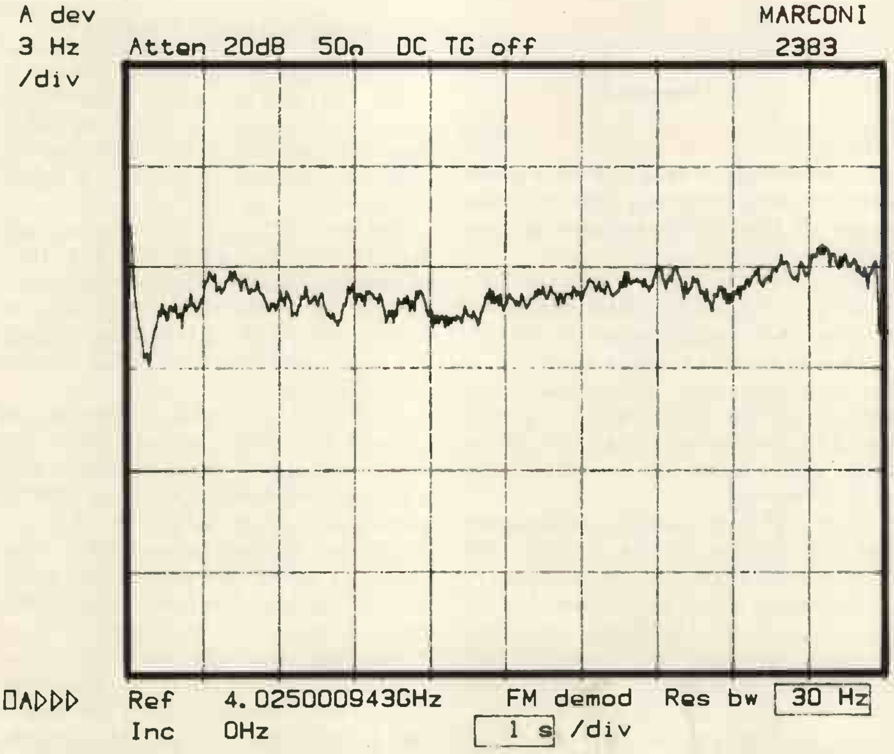


Fig.13. Measurement of residual f.m. on a 4GHz input signal using f.m. demodulation mode.

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BOOKS

Basic Electrical Engineering by E.C. Bell and R.W. Whitehead. Third edition, Collins, soft covers, 590 pages reproduced from camera-ready typescript, £12. Updated textbook from Bradford University's electrical and electronic engineering department, for first-year undergraduates, higher TEC students and students of other branches of engineering seeking to broaden their outlook. Emphasis is on practical applications.

Pattern recognition by Mike James. BSP Professional Books, £12. Introductory text at undergraduate level, covering basic image processing techniques from a practical engineering standpoint. Includes listings of various Basic subroutines. The author was until recently senior lecturer at Teesside Polytechnic and has worked with the image processing group at University College, London; this volume is a companion to his **Classification algorithms** (published in 1985). Soft covers, 144 pages.

Automatic control engineering by Francis H. Raven. Fourth edition, McGraw Hill, £12.50. Based on the author's course on control engineering at the University of Notre Dame in the US. Chapters deal with control components, steady-state operation, Laplace transforms, transient response, the root-locus method, state-space methods, analogue computers and digital control systems, frequency-response methods and system compensation. Soft covers, 566 pages.

BBC Basic 86 on the Amstrad PC's and IBM compatibles by N. Kantaris and K. Thompson: Book 1 – Language. Bernard Babani (publishing) BP243, £3.95. Introduction to the p.c. version of the widely-praised structured Basic developed for the BBC Microcomputer. Authors are with the computer department of the Camborne School of Mines in Cornwall. Book 2 will deal with graphics and disc files.

V-series microprocessors

To improve computing performance you can either throw your software investment away and start again or use a more advanced processor that runs existing programs.

IAN ROCK

High density integration is not simply a matter of finer patterns and smaller chips. As the integration density increases so, too, do the problems of heat dissipation. Complementary-mos technology, with its inherent low power dissipation, is an obvious solution to this problem. It has been used successfully in v.l.s.i. products for some time but, until fairly recently, was limited by the low speeds of early c-mos technology. As a result, advantage could only be taken of the increased complexity of v.l.s.i. where speed was not of primary concern.

By 1975, NEC had developed a c-mos process capable of producing highly reliable devices using 5.5μm geometry n-channel technology. Before the end of the decade, three generations of 8080 based microprocessors had been introduced, culminating in the μPD780.

The introduction of 16bit microprocessors in the early 1980s gave designers a choice of external bus configurations to suit the requirements of individual applications. Both the 8088 and the 8086, which soon became industry standard devices, had a 16bit internal bus with 8bit and 16bit external bus widths respectively.

Continuing to build on this established product base, NEC introduced the V-series V20/V30, Fig.1, enabling both new and existing equipment to benefit from significantly increased speeds. Besides being pin compatible with 8086 processors the V20/V30 can also handle all of the instructions of these earlier devices. Included in the set of 101 instructions are unique bit-field/bit-manipulation operators and PUSH/POP instructions for multiple register transfer.

Speed increases of some 30-40% are directly attributable to the introduction of a dual bus architecture, Fig.2. In single-bus processors, speed is restricted by the serial processing of frequently used two-operand instructions requiring two clock cycles. This bottleneck is eliminated by means of a 16-bit main data bus and a separate 16-bit sub-data bus arranged symmetrically about the register set. This concept improves the processing speed of all instructions linking two operands, by enabling the arithmetic logic unit (a.l.u.) to be loaded with 16-bit data while simultaneously transmitting 16-bit data.

Much of a processor's execution time is spent in address generation. Special hardware, designed to support effective address generation, recognizes the valid addressing mode in the instruction word, carries out the appropriate calculation and transfers the result into the data pointer register, DP, of the bus-interface unit. Only two clock cycles are required for effective-address generation, a function that would take five to twelve clock cycles using the normal microprogram method.

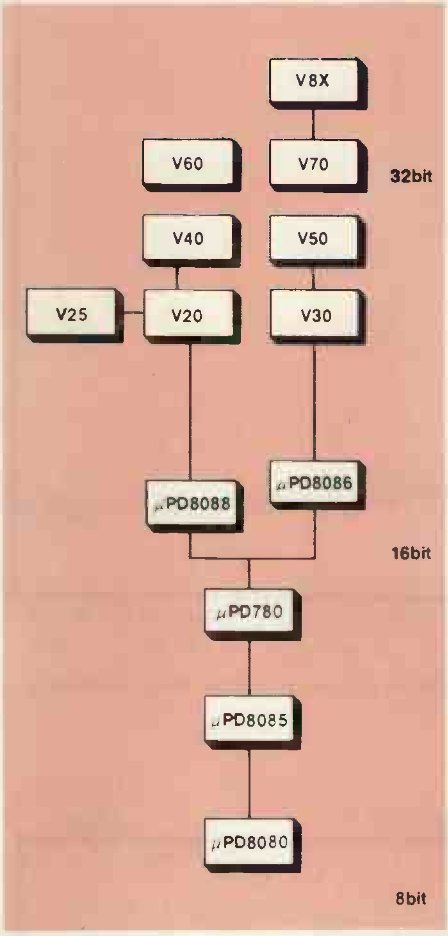


Fig.1. All microprocessors in the V-series family can take advantage of the extensive range of 8080/8086 software already available.

Other high-speed functions incorporated into the V20/V30 include a shifter that enables 16-bit multiplication/division to be carried out up to four times faster. A 16-bit loop counter also eliminates repetitious counting operations and increases shift/rotation and block transfer speeds by many times.

The two-level pipeline structure of the c.p.u. is supported by two program counters, one within the execution unit and the other, the prefetch pointer, in the bus-control unit, operating independently to increase execution speed even further.

In addition to the functional improvements incorporated into the V20/V30, a choice of 8 or 10MHz clock speed is also available and power dissipation is only around 500mW.

A development of the V20, the V25 is a complete single-chip microcomputer incorporating 16Kbyte of on-chip rom, 256 bytes of on-chip ram mapped into 1Mbyte of external memory space, and eight register banks. Program execution is optimized by a three-stage pipeline processor utilizing the dual data bus maximum speed.

On-chip peripherals include two serial channels, a programmable two-channel d.m.a. controller, and a three-channel 16-bit timer. Other features of the device include interrupt control with eight programmable priority levels and eight-bit external bus. Powerful and compact, the V20 is designed for applications such as process control and communications. A 16-bit version, V35, similarly based on the V30, is to be introduced shortly together with V25/V35 versions optimized for real time operating systems.

INTEGRATED PERIPHERALS

Higher integration capabilities and consequent increases in packing density have provided two potential development routes: greater complexity in microprocessor design, and the provision of on-chip peripherals for more compact systems.

The V40/V50 fall into the latter category. Based upon the V20/V30 c.p.u. their peripheral complement includes controllers for interrupts, direct memory access d.m.a. serial communication, timer, etc., classifying the V40/V50 as integrated-function microprocessors.

Identical 16 bit internal architectures and external 8bit (V40) and 16bit (V50) data buses characterize the processors. Total software compatibility with their V20/V30 predecessors is ensured by the same 101-instruction set, and an emulation mode continues the upward compatibility policy for 8080 software. The same bit field manipulation instructions, allowing high-speed processing, and addition/subtraction/comparison instructions for packed binary-coded decimal string data, are provided as well as basic arithmetic and logical instructions. These capabilities, and the ability to address up 1Mbyte of external memory space and 64Kbyte of i/o space independently, make the V40/V50 particularly suitable for graphics, binary-coded decimal, and electronic point-of-sale applications. They can enhance workstation power and add MS-DOS compatibility to low-cost terminals.

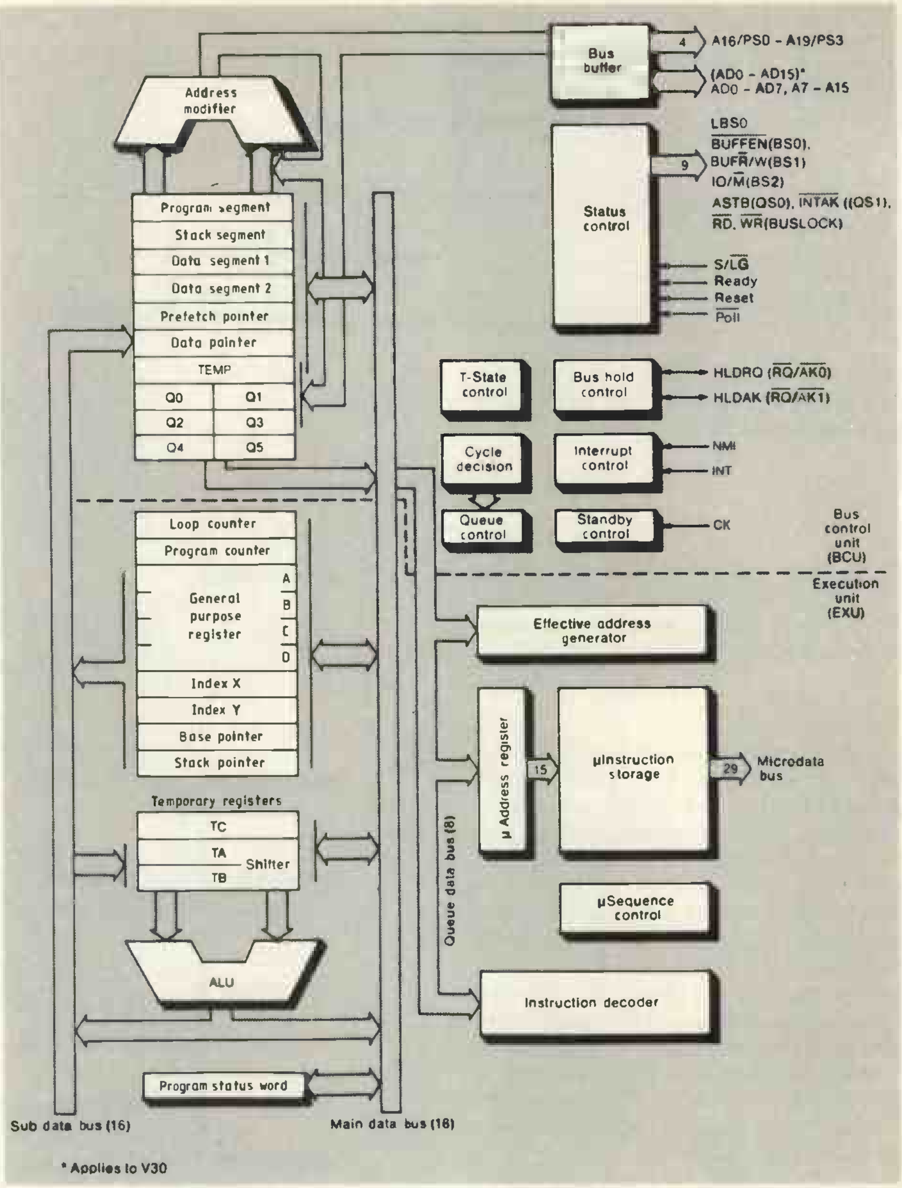
The introduction of the next generation of advanced microprocessors called for a series of detailed studies to identify the optimum architecture. It was concluded that 16-bit architecture would place restrictions on the development of future designs. A more general main-frame type of architecture was required as a basis for more powerful microprocessors, and the decision to move away from the classic V20/V30 architecture was made. The supermicro V60/V70 generation was to be based upon von Neumann architecture and would have a complex instruction set.

The strength of the instruction set of such a complex processor depends as much on the extent of its symmetry and orthogonality* as on the number of addressing modes and data types supported. The V60/V70 instruction set was created according to well defined guidelines – it had to be easy to decode and must support high-level languages. As a result, it is both symmetrical and orthogonal and supports 21 addressing modes with 14 data types.

The V60 operates at a speed of 3.5 million instructions per second and the V70, 6.6 million. Throughput is maximized by a six-stage pipelining architecture, Fig.3. allowing up to four instructions to be carried out simultaneously. These six stages are the bus-control unit, BCU, prefetch unit, PFU, instruction-decode unit, IDU, effective-address generator, EAG, memory-management unit, MMU, and the execution unit, EXU, Fig.4.

Pipeline processing begins with the prefetch unit, which continually fetches instructions and stores them in a 16-byte prefetch queue, PFQ, on a first-in-first-out basis. While the instruction is being executed, the instruction-decode unit decodes the next instruction from the prefetch queue, initializes the effective-address generator according to the addressing mode, and puts the decoded instruction into the decoded instruction queue, DIQ.

Activated by the instruction decoder, the effective-address generator reads and calculates the operand address then sends it to the memory-management unit for address translation. Effective addresses are then sent to the bus-control unit to fetch operands from memory. The execution unit, a 32bit processing unit consisting of microsequencer and arithmetic and logic unit, includes general and privileged registers. A three-bus structure connects the execution unit to the a.l.u., the barrel shifter and the effective address generator. Floating-point operations for both conventional arithmetic and conversion functions, are fully supported on-chip for 16 and 32-bit data. The IEEE 754 standard, with extensive error-checking, is also implemented.



* Applies to V30

Fig.2. On a microprocessor with a single internal bus, frequently used two-operand instructions have to be processed one operand after the other, taking two cycles. Having two internal buses increases processing speed by some 30 to 40%.

The V60/V70 instruction set is very large, comprising 273 instructions and accommodating both fixed and variable data sizes. Flexibility is enhanced by 21 addressing modes, and 32 general purpose registers are provided to ensure rapid code execution.

In 'native' mode, the instruction set is capable of handling system-management operations by providing high-level instructions for virtual-memory management, i/o, inter-process synchronization, and control-transfer operations. Special emphasis is laid on symmetry and orthogonality throughout the entire instruction set.

Layout of the register set plays a major role in the performance of both hardware and software. In the V60/V70, the 32-bit register set, which forms part of the execution unit, comprises 32 general-purpose, 23 privileged and two dedicated registers. This arrangement has the advantage that main memory does not have to be accessed for register manipulation or for effective-address generation.

The privilege register set is reserved for the management of program-execution and processor-control environments. It can be divided into four classes: memory-management, system-management and program-debug registers, and stack-pointer caches.

Consistent task and task-switching management is assured in multi-tasking environments by provision of special task and task-point registers, and the c.p.u. can address up to four gigabytes of virtual memory per task. The 4Gbyte virtual address space is divided into 1Gbyte sections each consisting of 1024 areas of 256 pages, each 4Kbytes deep. Address translation and memory management are overseen by on-chip hardware and firmware.

Memory protection for areas and pages can be set at four levels, level zero corresponding to the privileged level which can, generally, only be accessed by the operating system. Area protection specifies the least privileged level at which programs are permitted to access data, while page protection affects all information on the relevant page.

Microprocessor failure in systems such as satellite communications can be catas-

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*In a symmetrical instruction set, operations are reversible. For example, if an instruction SUB A,B exists, then SUB B,A also exists. Orthogonality describes regular and consistent treatment of operations among data types. If operation ADD is applicable to word-integer data types, it is also applicable to packed decimal, word-floating, and all other data types.

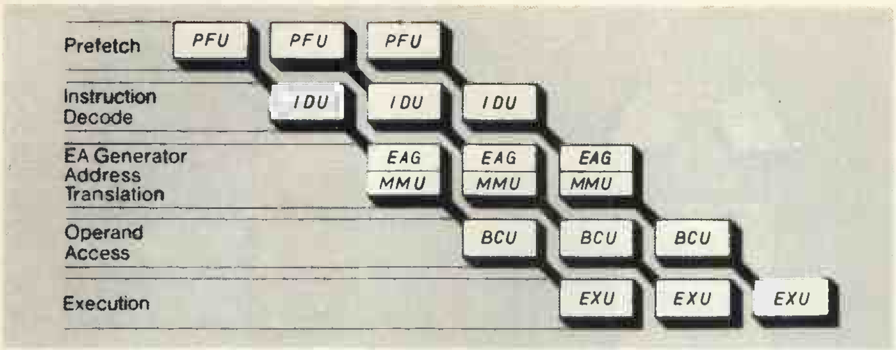

Fig.3. Six-stage pipelining in the V60/V70 processors allows up to four instructions to be carried out simultaneously.

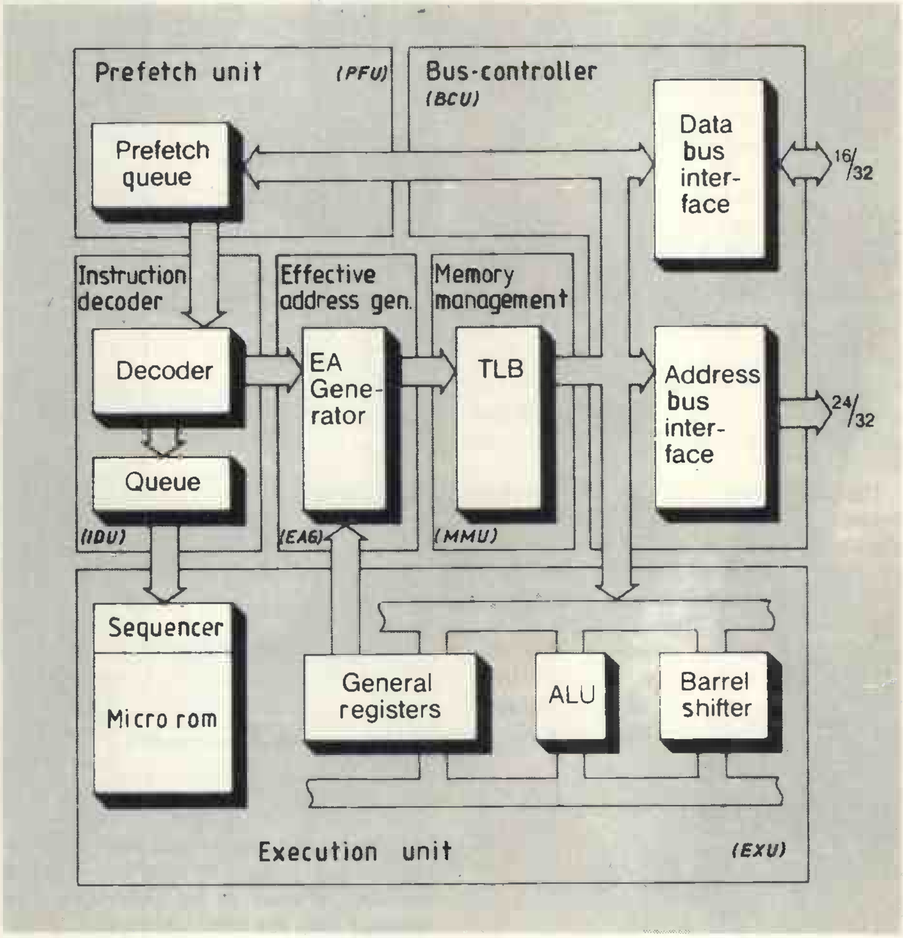

Fig.4. These six main elements of the V60/V70 processors form the six stages of the pipeline, starting with the instruction prefetch unit.

trophic. In order to ensure high reliability, fault-tolerant systems, V60/V70 devices are provided with a functional-redundancy monitor. A second (or subsequent) microprocessor, operating in parallel with the master device which is driving the bus, is used to indicate a malfunction if a mismatch occurs. The malfunction signal activates a fault interrupt line, common to all processors in the system, allowing the defective c.p.u. to be identified and the system to be reconfigured accordingly.

Already in development, the next generation of NEC supermicros, V80, extends the complexity, the flexibility and the speed of the V-series even further.

Ian Rock is Product Marketing Engineer with NEC Electronics (UK) Ltd.

I/O handling using C

A microprocessor with an internal data-base and macro service feature allows direct access of i/o peripherals by high-level languages such as C.

ALISTAIR GREENHILL

High level languages such as C expect all data to reside in the same address space, making direct access to peripheral systems difficult, even impossible. In order to handle peripherals residing in separate i/o address areas, assembly-level routines are required. Similarly, assembly-level routines may be necessary to switch between interrupt processing modules written in high level format.

The V25 16-bit single-chip microcomputer from NEC minimizes these tasks by incorporating two features which allow efficient handling of the internal peripherals directly from the C language. One of these features, a relocatable, memory-mapped internal data base, overcomes the problem of separate peripheral i/o addresses by mapping all the internal peripheral-control registers in one area. The second, a macro-service feature, performs predefined interrupt routines in microcode, removing the need to handle interrupts within C.

Software for the V25 is compatible with V20/V30 16-bit microprocessors, and eight register banks and powerful high speed interrupt handling improve performance in control applications. Figure 1 shows the internal structure of the V25, with on-chip features such as 16-bit timers, direct memory access controller, and serial interfaces.

Two 256-byte blocks form the internal data-base area. The lower block contains eight

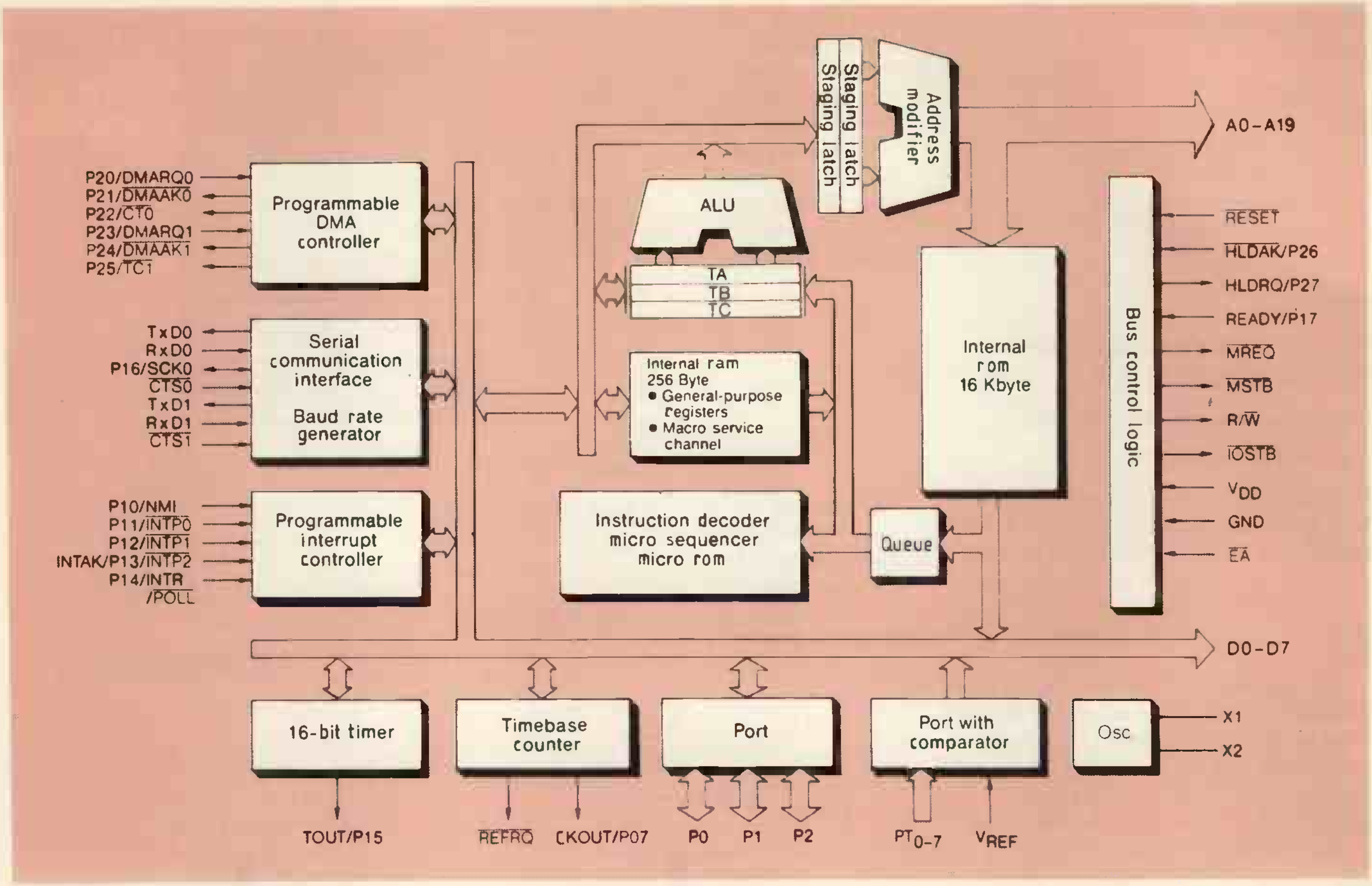

Fig.1. Internal structure of the V25 single-chip microcomputer. Besides a 1Mbyte address range and internal d.m.a. controller, this processor has facilities that allow high-level languages such as C to access peripheral i/o directly.

banks of general registers, of which banks 0 and 1 may also be used for macro-service or as d.m.a. control channels. All the internal special-function registers which control the integrated peripherals are contained in the upper block. The entire internal data-base area may be mapped into the top of any 4K block of the 1Mbyte address space. Within the data base the registers may be addressed as a byte only, as a word only, as a word or byte, or as a byte or bit.

The most efficient way of accessing this type of area in C is to define a structure made up of character data types (8-bit) and integer data types (16-bit). This structure is arbitrarily given the name s.f.r., or special-function register. Each element is given the name of the appropriate register as defined in the V25 user manual. The first few lines of the structure would look something like,

```
struct sfr      {
        char    P0
        char    PM0
        char    PMC0
        char    dum00[05]
        char    P1
```

This defines the port and port-mode registers, the dummy-character array being used to skip undefined address locations.

Since the internal data-base area is located in an absolute area of memory defined by the value in the data-base register, the position of the data base structure must be passed to any C program in the form of a pointer to an s.f.r. type structure. This can be achieved by defining an external variable at the beginning of any C source, for example,

```
extrn struct sfr * IDB;
```

The pointer must exist as a physical location in data memory, initialized with the correct value by a start up routine, normally written in assembler. This takes control from the RESET address and performs the following basic functions.

- Initialize the segment registers.
- Initialize the stack pointer.
- Define the location of the data-base area in memory by writing to location FFFFF$_{16}$ at which the data-base register is always located.
- Define a location called IDB which contains either a full pointer to the base of the internal data-base area or an offset from the data-segment register, depending on whether a large or small C model is used.
- Call the main C module, usually called _MAIN.

Within the C source program it with now be possible to refer to any register with the following structures.

```
IDB–>TMC0 = 0×33;
                 /* load timer control reg. zero */
IDB–>WTC = 0×2244;
                 /* load wait-state control reg. */
```

Byte or word addressing is automatically produced by the compiler.

To make the C source code more readable it is possible to define a set of key words as bit masks for each register such that the arithmetic sum of the required key words will produce a bit pattern which may be written to the appropriate register. Take for example the serial control register,

```
                                /* set up serial
                                channel 1 */
IDB–>SCM1 =ASYNC                /* mode; sync.
                                or async. */
            +TxEN
            +RxEN
            +CHAR__8            /* data bits:
                                also char 7 */
            +NO__PARITY/* no,zero,odd,
                                even possible*/
            +STOP__1;           /* stop bits
```

This produces the correct bit pattern because the following substitutions, defined in an 'include' file, will be performed by the preprocessor, List 1.

The logical way to deal with individual bit addressing would be to define each register as a union of character variable and bit-field

List 1. Serial control register definitions.

```
define ASYNC          1     /* asynchronous mode */
define SYNC           0     /* i/o interface mode */
define RxEN           64    /* receiver enable */
define RxDIS          0     /* receiver disable */
define STOP__1        0     /* 1 stop bit */
define STOP__2        4     /* 2 stop bits */
define CHAR__7        0     /* 7 data bits */
define CHAR__8        8     /* 8 data bits */
define NO__PARITY     0
define ZERO__PARITY   16
define ODD__PARITY    32
define EVEN__PARITY   48
define TxEN           128   /* transmitter enable */
define TxDIS          0     /* transmitter disable */
define CLK__INT       1     /* internal clock for i/o mode */
define CLK__EXT       0     /* external clock for i/o mode */
define TSK            8     /* trigger serial Rx clock bit */
```

variables for example,

```
union {
    char BYTE:
    struct {
        unsigned dum        :4;
        unsigned ENCS       :1;
        unsigned MS__INT    :1;
        unsigned TMMK       :1;
        unsigned TMF        :1;
    }BIT;
}TMIC1;
```

A byte write operation might appear as,

```
IDB->TMIC1.BYTE = 0×10;
```

and a bit write operation might appear as,

```
IDB->TMIC1.BIT.ENCS = 1;
```

Unfortunately C defines bit fields in integer-type data locations which result in a 16-bit quantity on the V25. Therefore a union of a character variable and a bit field will allocate two bytes of storage making it impossible to define two consecutive bit-addressable 8bit registers.

The solution is to define three pseudo functions, bit set, bit clr and bit tst which are used as "bit set (TMIC1,TMF);". This causes the timer mask flag, TMF, in the first timer-mode register to be set. Define statements in the appropriate 'include' file will cause the pre-processor to produce,

```
IDB->TMIC1 = IDB->TMIC1 | 0×80;
```

which will force the compiler to manipulate register TMIC1 using byte reads and writes.

To facilitate these operations all bit names are defined with a value equivalent to an 8bit mask with a bit set at the appropriate position. For example the timer mask flag, TMF, shown above is converted to 128 = $1000\ 0000_2$ by the pre-processor.

Macro service describes a function of the V25 microcomputer which behaves like a cross between an interrupt and a direct memory access transfer. Any interrupt may be selected to behave in one of three ways.

In a conventional interrupt, present processor status is pushed to stack and program flow vectors to an interrupt routine. A context switch interrupt saves present processor status in temporary registers within the current register bank, the register bank is switched and processing immediately continues as defined by the registers in the new bank. Macro servicing is the third interrupt type.

Macro service interrupts cause the c.p.u. to pause between execution of two instructions while the microcode executes a single memory-to-memory data transfer. Internal data paths are used, but this has no effect on any of the working registers, other than those defined as the macro-service control channel. The transfer must always be between a memory-mapped control register in the internal data-base area and a memory location anywhere in the 1Mbyte address space. Either eight or sixteen bits may be transferred on each occasion and for 8bit transfers a data comparison option may be selected.

Control of macro-service operation is similar to control of direct memory access in that a register-based control block is selected for each active channel. Eight macro-service channels can be operated at any one time, and

Fig.2. As with d.m.a., macro services require that a register-based control block is selected for each channel. These blocks are mapped within register bank zero.

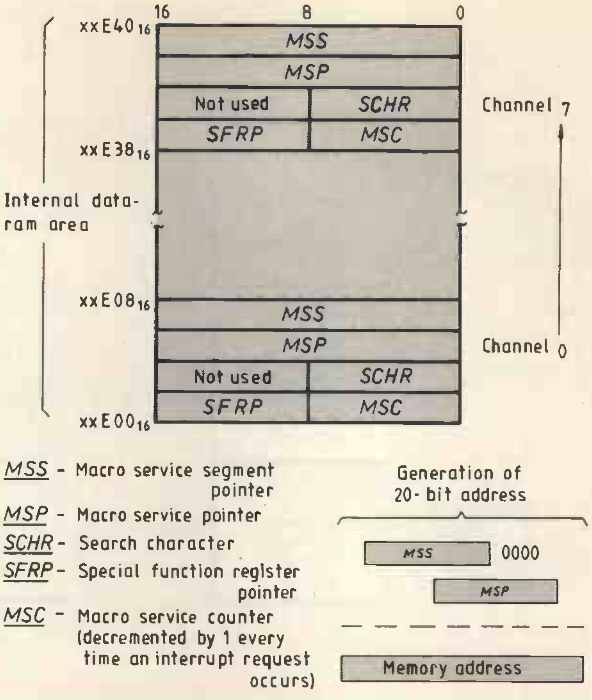

Fig.3. Typical macro service for transmitting up to 256 characters followed by a null on serial channel one.

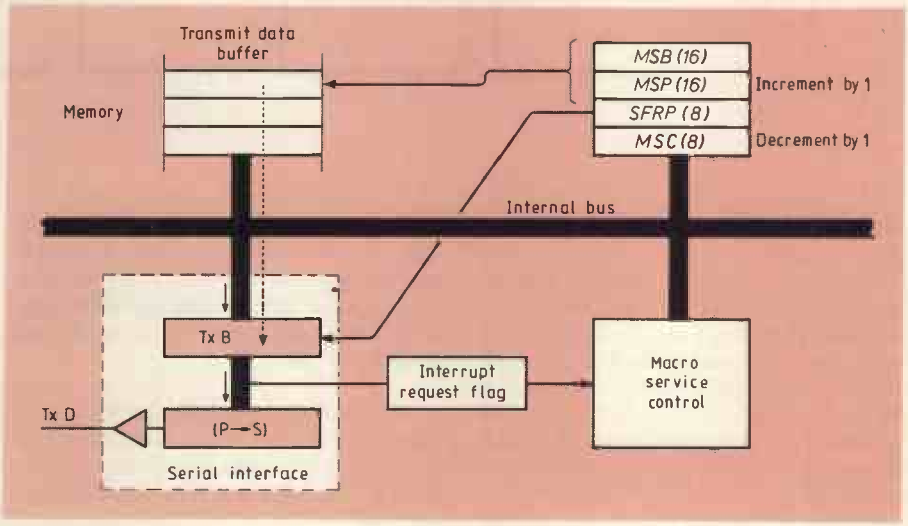

Fig. 3 shows how these blocks are mapped within register-banks zero and one. The macro-service control block contains the following; 16bit segment and 16bit offset memory pointers; an 8bit offset address within the data base to the required special function register; an 8bit transfer count, and an 8bit search character.

Figure 4 shows a typical example of a macro service in use. Here, a string of up to 256 characters, terminated with a null character, is to be transmitted by the first serial channel. The data-base address pointer is set to the transmit-buffer address and macro service selected for the buffer-empty interrupt. The memory pointer is set to the beginning of the character string and the search character is defined as null. As the string length is unknown, the transfer count is set to the maximum of 256.

In operation, a character will be sent to the transmit buffer automatically on each interrupt, incrementing the memory pointer and decrementing the transfer count on each occasion. When the search character is detected or the transfer count reaches zero, the macro service will be disabled and the normal interrupt-request flag set. This request may be handled by polling, standard interrupt or a context switch.

Since the macro and d.m.a. control channels are memory mapped, they may easily be referred to by C. The s.f.r. structure can include definitions of the control blocks to allow reference to macro channels 2-7 thus,

```
IDB->CH3.MSP = 0×1122;
```

load macro service ch. pointer with 1122_{16}

Channels zero and one may be used either for direct memory access or macro control, therefore the use must also be defined,

```
IDB->CH0.MAC.MSC = 0×77;
```

load macro service counter ch.0 with 77_{16}

```
IDB->CH1.DMA.TC = 0×4455;
```

load d.m.a. ch. 1, terminate with 4455_{16}

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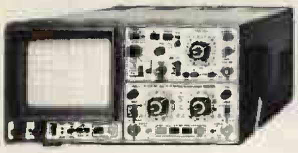

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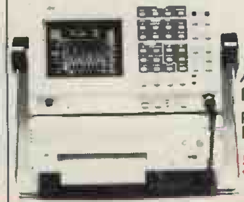

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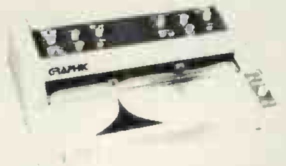

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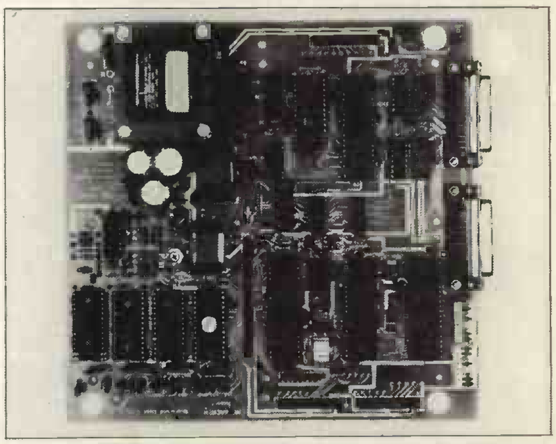

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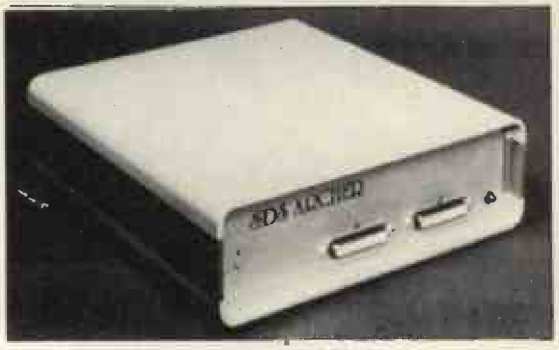

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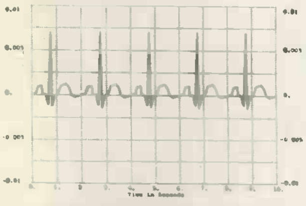
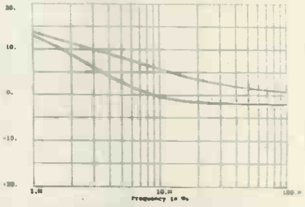


Waveform through switching circuit



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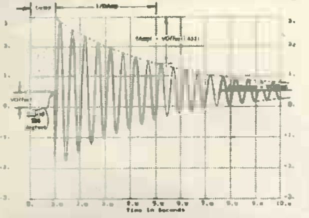
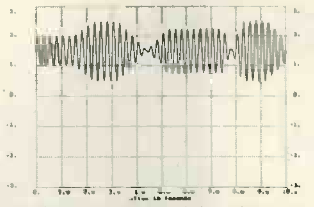


Internal generator programmed to produce sine wave with exponential amplitude decay



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Variations on the theme of patents

Inventors can find it very difficult to obtain the protection that patents are supposed to provide.

R.J. REDDING

If one invents some radically fresh form of rodent exterminator – as opposed to a better mousetrap – then patents are unlikely to be much help to the inventor. Most radical changes take at least 20 years to implement and so the original patent rights will have died before recognition occurs. Sometimes an active and vocal inventor might get recognised in 10 years, only to face a similar period of legal battles.

A reputable organisation will not deal with an inventor unless the ownership of ideas is clear. The patent system is a time-honoured practice which works at least for a simple clear cut case which can be handled by one organisation. If, however, one discovers some technique that is widely applicable or can influence the future of a whole industry then it is a different matter and becomes one of National concern.

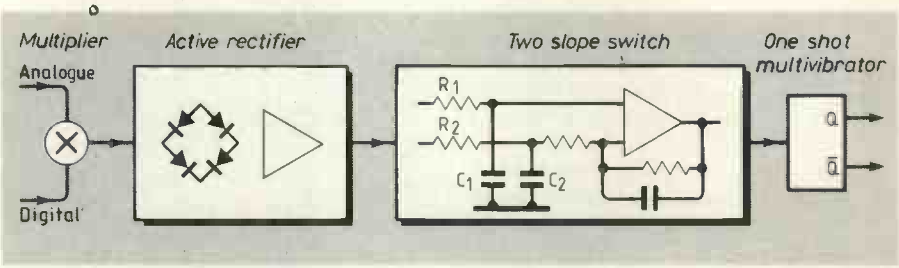
An invention like the transistor and the microprocessor has resounding effects everywhere, but we have to find the right way to apply it. The lone inventor may see a widget to eliminate an intractable problem, but what can he do about it? A entire industry has to be convinced before it will move and no amount of Government exhortation or pump-priming money will necessarily cause this to happen. Yet unless an industry exploits its opportunities, then the country is bound to go into a decline in comparison with more adventurous ones.

Though the UK is good at inventing, it is not so adept at applying and making real worthwhile steps forward, and hence the 'brain drain' and the fact that many inventions that start in the UK are bought back from abroad many years later.

However, such generalizations get us nowhere. Let us take some specific examples, which perforce will be somewhat personal because my aim is to point out some pitfalls – and new opportunities for the individual, for it takes enthusiasm and the right idea to make it happen, and here is the inventor that matters.

EXAMPLE FROM INSTRUMENTATION

Take for example measurement and control technology which is surely an important one, since it enables electrical, mechanical and chemical engineers to talk to one another and control their processes! The instrument man's dials and pointers are gradually being replaced by electrical signals (I have been working on this for over 40 years) and the further move to all-solid-state electronics is painfully slow.



One patent that might never have been granted was this speech scrambler intended for use with CB radio and radiophones. The US National Security Agency decided that it could use the system and slapped a secrecy order on it. After a news story in *Science* and the intervention of a senator, the order was rescinded and the Phasorphone became US patent No. 4,188,580. Details of national and international patents are available through the UK Patent Information Network at major public libraries throughout the country.

Consider the measurement of liquid and gas flow. The vast majority of flowmetering is on the basis of putting in a flow restriction (orifice plate or venturi) and seeing how much energy is lost across it. There are all-electrical ways; for example, Michael Faraday demonstrated on the River Thames in 1890 how to use the earth's magnetic field, but only a few per cent of industrial flowmeters use that principle today.

Let us take, as an example, one of the few innovations in flow measurement in the last decade. A small company in Colorado evolved a new flowmeter about 1973 based on Coriolis forces. This is the principle of the gyroscope and inertial navigation. If something is rotating, then there is a resistance to a change in the plane of rotation. This resistance is a measure of the mass and the velocity. Consequently the new bright idea was to form the fluid pipe into a circular orbital path, so that the Coriolis effect causes a twist in the tube. Using magnetic sensing and vibrating the tube for extra sensitivity, this could be resolved into an electrical signal whose frequency represented mass flow.

Eventually this was tried on some very difficult fluid such as toothpaste and ice cream (which is rather inconvenient for orifice plates) and it gained a reputation for measuring foods and similar substances.

Around 1980 there was a move to amalgamate instrument companies by associating a number to give complete coverage of industrial requirements, so the new company was a unique take-over acquisition. This seemed to excite the competition because several other Coriolis flowmeters started to appear and a writ for a patent infringement was issued against one of them.

Now a small upstart company has little chance against the might of a conglomerate but a further would-be-king intervened, and so it became a battle of the giants. The eventual outcome that the patents were not upheld, so we now have two conglomerates at logger-heads and anyone can make the same sort of thing, and the originator is probably feeling very sorry for himself.

I write this with feeling, because I have an even broader method of flow measurement which doesn't need the tube arrangement at all, and works directly by converting the fluid velocity into hertz via a sound wave, by solving the equation for wave motion. What is more, it works on gases as well as liquids, and is currently being examined by British Gas for use in a domestic gas meter. I hold patents on this in a number of countries, so what can I do with them to avoid getting into the same mess?

PROBLEM FOR THE ENTREPRENEUR

Companies readily explore an invention but it takes a "product champion" or a persistent lone inventor to go in opposition to the rest of the world and provide something new. Even then it will be difficult to get the resources and the backing without giving some of the rights for the product and most organisations will want an exclusive license on the patent rights.

If the product has a wide impact or universal application then the exclusivity of patents seems disadvantageous. It would be

Continued on page 287

Tiltmeter

This instrument can show the movement of the floor under the weight of a person or the continental tilt caused by the Sun and Moon.

A. REFSUM

This article describes a mercury level with which one can detect changes in the gravitational horizon of the order of 10^{-9} radians.

Its general arrangement is shown in Fig.1. Two plastic cups are partly filled with mercury. The mercury and the air above communicate through tubes 1 and 2 respectively. Above the mercury pools are two metal discs a and b which can be screwed down until the spacing is typically 0.5mm. The mercury in the cups and the discs above form two air-spaced capacitors C_a and C_b. If the arrangement is tilted, mercury will flow from one end to the other and change the levels in the cups. This changes the capacitances differentially and the change can be sensed electronically.

In the basic bridge circuit (Fig.2) a 1MHz oscillator provides excitation to the capacitors. At balance there is no voltage between the common mercury electrode of the capacitors and the mid point of the excitation coil; any imbalance will generate a voltage between these two points, which is amplified and phase-sensitive rectified for an unambiguous display of the tilt.

If a small change δs in s, the height of the disc above the mercury, results in a voltage δu across the balance points when the bridge is driven by a voltage U, then, neglecting any stray capacitances, these quantities are related thus:

$$\delta u/U = \delta s/s$$

Neglecting fringing, the capacitance of a parallel-plate capacitor is given by $e_0.A/s$. If the minimum readily detectable voltage δu is 10μV with a driving voltage U of 10V and a mercury-disc spacing s of 1mm, then the minimum detectable change δs is one nanometre. For comparison, the wavelength of visible light is about 0.5nm. The tilt that will cause this shift depends on the baseline. If this is assumed to be 1m, it follows that the angle of detectable tilt is one nanoradian. This represents about the thickness of a florin over a 150 mile baseline.

FLUID BALANCE

Mercury flows from one cup to the other under the influence of three effects:

gravity: $p1 = \rho.g.h$
inertia: $p2 = \rho\,(S-D)\,dv/dt$
viscous friction: $p3 = 32\,(S-D).\mu.v/d^2$

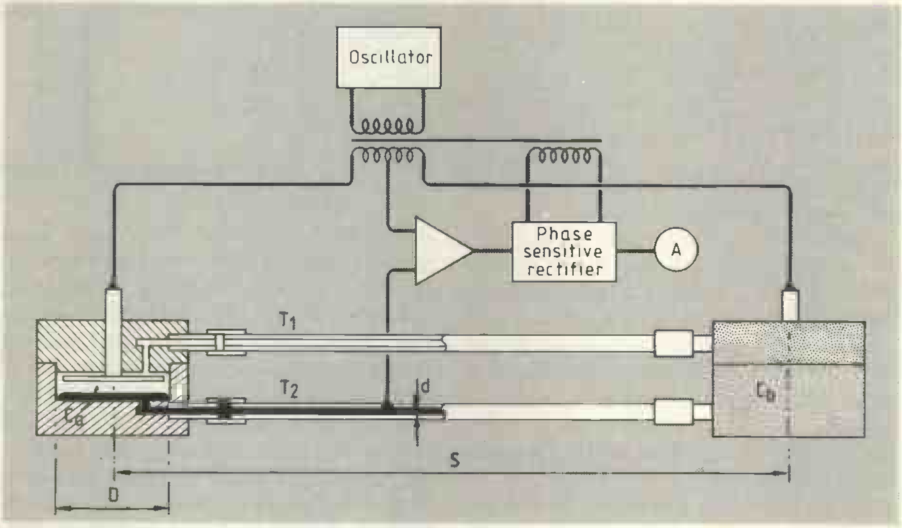


Fig.1. General arrangement of the tiltmeter. Any displacement of the mercury brought about by tilting alters the capacitance between the mercury surface in the cups and the discs above.

The rate of displacement of mercury from one cup to the other must be equal to the rate of flow in the connecting tube:

$$½.\frac{\pi D^2}{4}.\frac{dh}{dt} = \frac{\pi d^2}{4}.v$$

As the level in one cup falls, the level in the other rises. The difference in levels therefore changes twice as fast as the level in either cup – hence the leading factor of ½ in the fluid continuity equation.

The three pressures sum to zero,

$$p1 + p2 + p3 = 0$$

This can be reduced to a single, linear, second-order differential equation:

$$\frac{1}{\omega_0^2}.\frac{d^2h}{dt^2} + \frac{2\xi}{\omega_0}.\frac{dh}{dt} + h = \text{disturbance}$$

$$\text{Periodic time } T = 2\,\pi\,\sqrt{(S-D)/2/g}.D/d$$

$$\text{Damping factor } \xi = T.8.\mu/\pi/\rho/d^2$$

This shows that the response is a damped oscillation. Damping can be made critical for baseline S=750mm with cups D=90mm if the connecting tube is of 3.5mm diameter. In this case the periodic time of the tiltmeter is 29.6s, with a damping factor of 0.706 (the density of mercury $\rho = 13550\text{kg/m}^3$, viscosity $\mu = 1.554$g/m/s and $g = 9.81$m/s/s).

ELECTRONIC CIRCUIT

In the electronic circuit (Fig.3) Tr_1 and Tr_2 form a push-pull oscillator. The frequency determining factors are the inductance L and capacitors C_a, C_b. Tr_3 to Tr_6 form a long-tail compound gain pair followed by Tr_7-Tr_{10} in a current-switching phase-sensitive rectifier.

The 50-0-50 microammeter senses the average current difference between the two sides of the current switch. Since the instrument may be subject to ±1mA current excursions, a shunting resistor R_{10} is best left in the circuit until balance is approached.

Circuits using fewer than 10 transistors can readily be devised. However, the stability and lack of critical components in the present design make it hard to beat. For ease of adjustment and stability, the potentiometer R_{11} should be a multi-turn type and R_8, R_9 high stability types. Frequency drift in the oscillator, transistor gain spread and temperature drift have comparatively little effect.

MECHANICAL DESIGN

Main components are shown in Fig.1 with typical dimensions. The cups can be made

“You can detect a man standing on a concrete floor...”

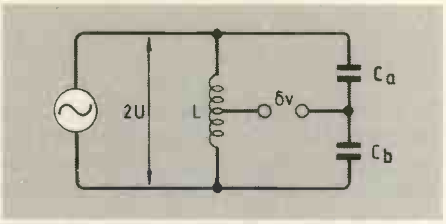


Fig.2. Imbalance between the two capacitors (the mercury cups) will result in an output from the bridge.

from 25mm Perspex; the machining is not very critical.

The discs are best made from stainless steel. Again, dimensions are not critical. The stem should be square on the disc and have a fine thread, 0.5mm or less. Fine threads are readily machined on a lathe, but the tap for a fine thread is more difficult to come by. If the stem is taken through the perspex lid directly, drilling an undersized hole and just forcibly screwing the stem through, while still lined up in the lathe, may be adequate.

Connecting pipes should be stainless steel or glass. If stub ends are screwed into the perspex cup and lid, heat-shrink plastic tubing can be used to connect the pipes to them.

The whole assembly should be mounted on a very firm base. A two-inch slate slab from an old switchgear panel is one economic solution. A monumental mason may be helpful with shaping the base.

Once mounted, the device must be set up level on a very solid foundation. A good concrete floor is adequate for simple observations, but for long term use bedrock is necessary.

Mercury slowly gives off a vapour which is cumulatively poisonous. Spillage should therefore be avoided. The apparatus should be filled with mercury only when it is in its final, well ventilated position. A very deliberate approach should be adopted to the filling with every stage carefully rehearsed.

Mercury very readily forms a dross on the surface. One way to avoid getting dross into the apparatus is to suck it in through a branchpipe in the lower pipe from below the surface of the mercury in the storage jar. The branchpipe in the lower pipe must have a stop-cock and the pipe into the storage jar must be very carefully drained after use.

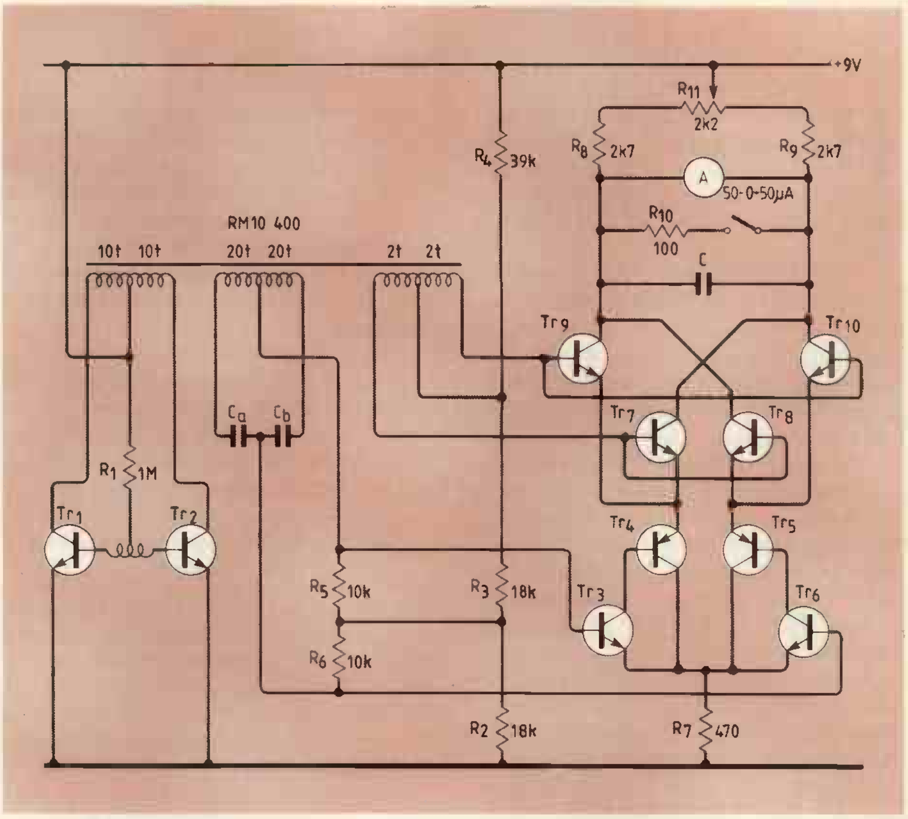


Fig.3. Circuit diagram of the electronic module. An i.c. could be used for the phase-sensitive rectifier.

Sealing the end with ‘Blu-tack’ is one way of trapping the last irremovable drop from the this pipe. This approach requires access to the underside of the apparatus. When the mercury is to be sucked in, the cups must have temporary airtight lids with one suction pipe fitted. The mercury surface in the cups may be kept clear if a very small amount of silicone oil is dropped on the surface.

CALIBRATION

The long hydraulic time constant makes it a slow process to balance and calibrate the tiltmeter. From the machining of the thread on the disc stem the pitch should be known. If not it must be determined. When first filled the tiltmeter must be given time to settle hydraulically before electrical balance is attempted.

This should be made with a fair spacing between the mercury and the discs. Measuring the frequency of oscillation with added capacitances across the cups will, through repeated use of the L-C resonance formula, give values for L and C. The latter will include any stray, but varying the cup capacitance by reducing the mercury-disc spacing by known amount should make it possible to separate the two. The frequency at final gap setting can then be used to infer the value of this setting. Stray capacitance changes the multiplier δC.s/C implied in the equations above but not the general form.

Reference

C.L. Strong. A sensitive tiltmeter that serves as a seismometer. *Scientific American* November 1973.

Dr Alf Refsum is a senior lecturer in the electrical and electronic engineering department of The Queen's University of Belfast.

Microcoding and bit-slice techniques

Microcoding for a prom can be designed on a large sheet of paper, but there are more elegant solutions in the form of software tools.

A. N. EDMONDS

Having determined the hardware of a microcoded system, like the controller and 16bit c.p.u. that I described in the January issue, the designer is left with a group of lines intended for microcode control.

Normally, each control line connects to the output of a registered prom, the lines being grouped into fields in an orderly fashion, and all the proms receive their addresses from the same bus. With the first design iteration there may be too many lines – or indeed too few.

One way of microcoding a prom is to laboriously draw a representation of the prom contents as a matrix of ones and zeros on a large sheet of paper. During this task, it soon becomes obvious that particular patterns occur repeatedly and that particular groups of bits will take only a limited range of values.

As you might expect, there are software tools that simplify and speed up this slow and error-prone process, and that allow you to take advantage of patterns that occur.

META ASSEMBLERS

Assemblers designed to produce code for any destination hardware are called meta assemblers. To be able to produce code for any destination hardware, meta assemblers first need to be fed with specific information about the hardware configuration. Figure 1 shows the stages involved in using a meta assembler.

All meta assemblers have a definitions phase and an assembly phase. During the definitions phase, the following are defined,

- physical lines to be controlled
- fields for groups of lines
- positions of fields in the bit map
- a list of field names.

These definitions form the vocabulary of the assembly language. When making a list of named values that each field can take, it can be possible to define macros grouping commonly occurring field assignments.

In the assembly phase, this language is used to produce object code. At this stage, the hardware is effectively transparent and late changes in hardware can often be catered for by simply altering parameters determined during the definitions phase.

The syntax and facilities of the assembly phase of a meta assembler differ little from those of any other assembler. In a normal assembler, a source-code line consists of instructions and operands or directives that may produce several words of code when assembled.

A line of meta-assembler source code consists of field assignments or assembler directives, and one source-code line describes all the parallel actions that must occur in that one cycle. After assembly, this line becomes one row in the control store.

META ASSEMBLERS CURRENTLY AVAILABLE

The now extinct father of meta assemblers was a product called Amdasm from Advanced Micro Devices. Several companies now produce assemblers that are 'upwards compatible' with Amdasm, such as Meta29 from Microtech Research, and since Amdasm is the basis of these I will give examples in it.

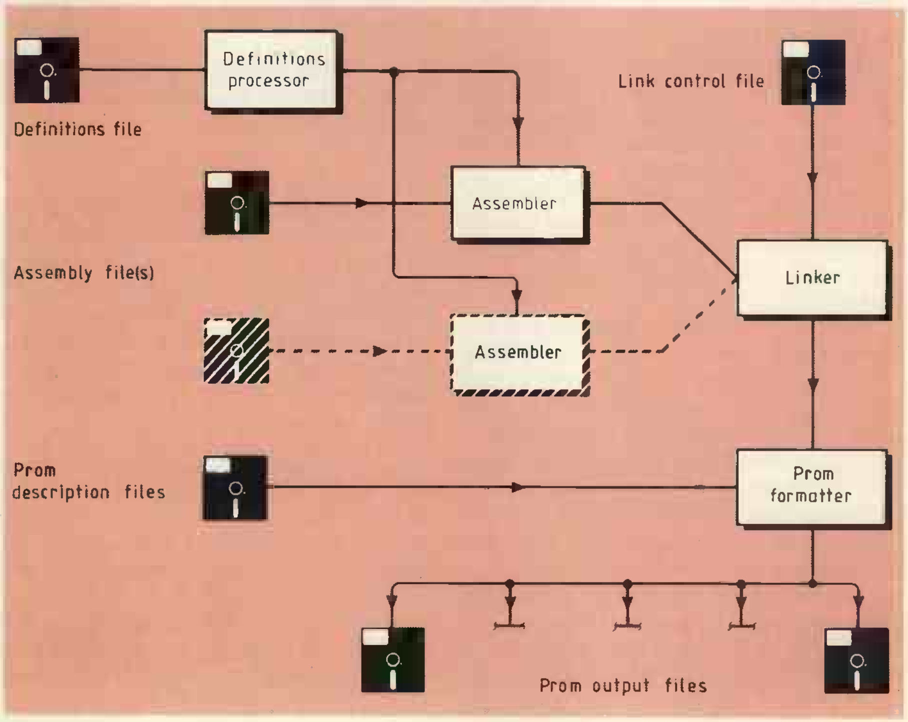
A company called Step Engineering has produced Metastep, my personal favourite, which has a C-like structure making comprehension and maintenance simpler. Amdasm source files can be converted only with difficulty into Metastep form, and the inverse is impossible, so it will be easier to show Metastep examples separately. Amdasm ran under CP/M; all the other meta assemblers are available for a number of computers including the Vax and IBM PC.

DEFINITION

Using the sequencer design in the January issue, I will attempt to show how a meta assembler definitions file can be built up.

List 1 shows the definition of the sequencer in Metastep syntax and List 2 the same in Amdasm. Both of these say the same

Fig.1. During its assembly phase a meta assembler is much like any other assembler, but since it can assemble code for any destination hardware it must first be fed with specific details about the hardware.



thing: width of the microword is 48 bits, the lowest 12 bits form a next-address field with default zero, and the 2910 instruction-set field is contained in next four bits. The instruction-set field of the 2910 microprogram controller can take on the 16 values given with the mnemonics supplied.

Metastep and Amdasm differ in the way that they treat symbols. In the Metastep definition, 2910 mnemonics are local to the 2910 field, i.e. you could re-use the same mnemonic in another definition without conflict. In Amdasm, labels of EQU equate statements are valid globally. The Metastep 'values' statement also prevents the use of any symbol other than those given with the particular field.

In List 2, the line,

```
I2910: DEF 32X,4V,12X
```

looks complex but merely states that label I2910 will be concerned with a four-bit variable field surrounded by don't care values and set 12 bits from the bottom of the microword and 32 bits from the top. The Metastep definition speaks for itself.

DEFINITION FACILITIES

For the definitions process, the assemblers offer different functions. Common features are the position and size of a field within the bit map, its default value, and the values that it can hold.

Other features can be very useful. Microcoded systems can often have highly pipelined data paths which means that the control path can be skewed in time with respect to the data path, and that instructions to some fields must be issued in different cycles to others. Metastep gives you the opportunity to describe these pipelining skews in the definitions file and render them transparent to the assembly code.

Macro facilities are common, enabling frequently occurring groups of field assignments to be represented by a shorthand symbol with optional parameters. Judicious use of these can make assembly code much more comprehensible.

Field assignments are not always static. Sometimes a group of control lines can be used for several purposes. For instance, a four-bit control field and a 12bit address field may occasionally be used together as a 16bit coefficients field so two field definitions are needed for the same control lines. Some meta assemblers allow this to be done.

In defining the vocabulary for an assembly language, it is possible that there are combinations of field assignments that need to be avoided to prevent contention or nonsensical states. Some meta assemblers provide a way of doing this, resulting in an error flag or warning during assembly.

Finally, all assemblers provide a means of truncating, inverting, sign-extending or otherwise manipulating values supplied to field assignments.

PRODUCING AN ASSEMBLY FILE

Using the Amdasm definition above, the following is a potential code fragment for a conditional loop.

```
START:  I2910 CONT
        I2910 CJP & NXTADD START
```

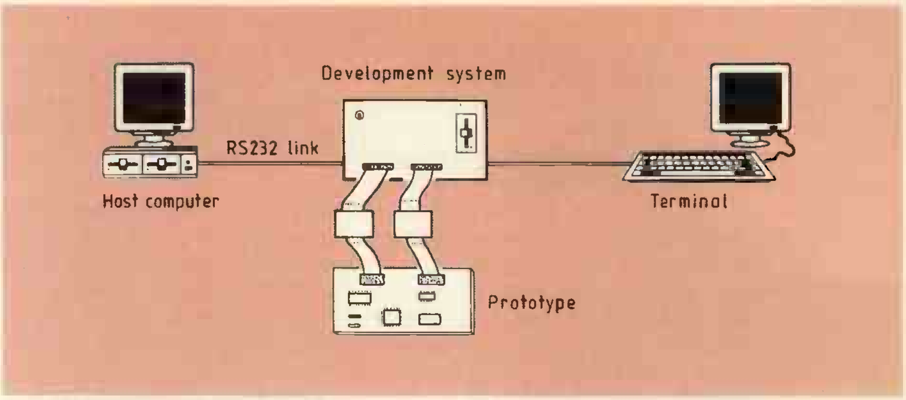


Fig.2. In a microcode development system, the microcode prom for the board under development is simulated in ram. Development systems are fast and convenient, but they are expensive and can tempt the tweaking of microcode at bit level rather than through the adjustment of source code.

where CONT, CJP and START take the place of the variable field in I2910 and NXTADD. Several field assignments can be included on one line, separated by an ampersand. Amdasm produces the final code for each line by Oring all the field definitions together. It also reports overlapping field definitions. Metastep is more long winded,

```
START:  I2910 = CONT;
        I2910 = CJP, nextaddr = START;
```

One of the strengths of Metastep is its ability to handle macros covering common collections of field assignments. For instance, a macro called jump in the definitions file defined as,

```
macro       jump &1;
begin
      2910 = CJP, nextaddr = &1
endm;
```

would enable the code fragment above it to be rewritten as,

```
START:  2910 = CONT;
        jump START;
```

This improves readability, helps comprehension and further hides the hardware.

ASSEMBLER FACILITIES

Designing something like a processor involves writing many different sections of code, most of which are independent of each other. Some external hardware configurations force the sequencer to point to the start address of each of these as they are required. These start addresses may already be fixed, or they may be subject to a constraint such as having their least-significant four bits made zero.

The remainder of each code section does not have to be fixed in the same way, and efficient use of microcode memory will often dictate that it should be separated from the start address. For example, if the system decoding hardware determines that two functions have contiguous addresses, yet they are both longer than one cycle, then subsequent code must be put elsewhere and linked by a jump. It is not important where the subsequent code goes, as long the linking function can find it.

There are thus two types of code – absolute and relocatable. Most assemblers can handle this as long as you define two segments and show which code is in which. An ORG origin statement will tether the absolute segment to the address given.

ASSEMBLER OUTPUT

What you want out of an assembler is the hexadecimal code with which to program proms. Having successfully assembled your source code, two more stages remain, name-

List 1. Definitions of a sequencer in Metastep syntax.

```
demopro: instruction version ('1.00'), length(48);
nextaddr: bits(11..0), default(0);
/* The next address field for the sequencer */
2910:          bits (15..12),
               values  (h'0': JZ,     h'1'  : CJS,
                        h'2': JMAP,   h'3'  : CJP
                        h'4': PUSH,   h'5'  : JSRP,
                        h'6': CJV,    h'7'  : JRP,
                        h'8': RFCT,   h'9'  : RPCT,
                        h'a': CRTN,   h'b'  : CJPP,
                        h'c': LDCT,   h'd'  : LOOP,
                        h'e': CONT,   h'f'  : TWB),
               default (CON);
/* the 2910 instruction field */
endInstruction;
```

List 2. Sequencer definitions in Amdasm syntax.

```
;
WORD 48              ;
; THE NEXT ADDRESS FIELD
; BITS 0 TO 11
NXTADD: DEF 36X,12V:%H#000
;
; 2910 INSTRUCTION SET
JZ:         EQU   H#0   ;
CJS:        EQU   H#1   ;
JMAP:       EQU   H#2   ;
CJP:        EQU   H#3   ;
PUSH:       EQU   H#4   ;
JSRP:       EQU   H#5   ;
CJV:        EQH   H#6   ;
JRP:        EQU   H#7   ;
RFCT:       EQU   H#8   ;
RPCT:       EQU   H#9   ;
CRTN:       EQU   H#A   ;
CJPP:       EQU   H#B   ;
LDCT:       EQU   H#C   ;
LOOP:       EQU   H#D   ;
CONT:       EQU   H#E   ;
TWB:        EQU   H#F   ;
;
12910:      DEF   32X,4V,12X
;
END
```

ly linking and formatting. Most meta asemblers allow you to write wholly in terms of symbolic addresses. During the linking stage, these addresses are fixed and several object files can be stitched together.

The formatter takes absolute-address object code from the linker and divides it into files corresponding to the way that the microcode will be physically contained in your proms. You must therefore tell the formatter how your hardware is arranged. Usually, it is also possible to specify an output form, such as Intel hex or Ascii, to suit a particular prom programmer.

DEBUGGING

Having put the code into proms and run the system, you will usually find that it does not work. Debugging a microcoded system is much like debugging anything else; the first requirement for eliminating a bug is to find it.

But unlike a microprocessor, in which the functions are enclosed and internal states must be inferred (unless in-circuit emulation is used), bit-slice hardware allows you to apply a logic-state analyser at the heart of the system. Functional blocks in a bit-slice processor operate faster but are simpler than those of a microprocessor, and bugs can seldom hide for long, even in the most complex of circuits.

The problem with microcoded systems lies in updating and correcting the microcode. Obviously, a new set of proms can be programmed each time that a bug is found, but fast proms are expensive and can usually only be programmed once. However there is a range of erasable registered proms from Cypress.

Erasable proms have the added advantage that the person doing the debugging is forced to correct the bug at the highest level, that is in assembly language at either the definition or assembly phase. Thus the final software source code will represent the final debugged system.

A second solution involves use of a microcode development system. These devices replace your microcode proms with plug-in adaptors on flying leads connected to two-port rams. The two-port rams, contained in the main housing of the development system, Fig. 2, are known as a writeable control store.

Development systems are normally supplied with a processor and terminal, and permit very fast changes in microcode. But they are also very expensive. Development systems that allow the prototype to run at full speed must have control stores made from costly high-speed e.c.l. rams.

The drawback with development systems is that they tempt the operator to tweak the microcode at bit level rather than at source-code level, leaving the source code unrepresentative of the final working prototype. Trying to make the assembly language match the code in the proms so that the design can be reproduced can be a nightmare.

Development system manufacturers have realized this, and have made it possible to edit and reassemble the source-code in the development system itself, thus keeping the software in step at all levels.

There is a third solution to debugging, and that is to design a debugging aid into the system. One could build a prototype using ram, two-port or otherwise, as a microcode store. As a means of loading the ram, a PC-based parallel interface could be used for example.

Bit-slice i.cs from Analog Devices simplify built-in debugging by providing hardware assistance and dedicated commands in their sequencer. The problem here is that you have to write your own control software, either for the PC or for the prototype.

Andrew Edmonds is consultant digital design engineer and Director of Guyvale Ltd, Olney.

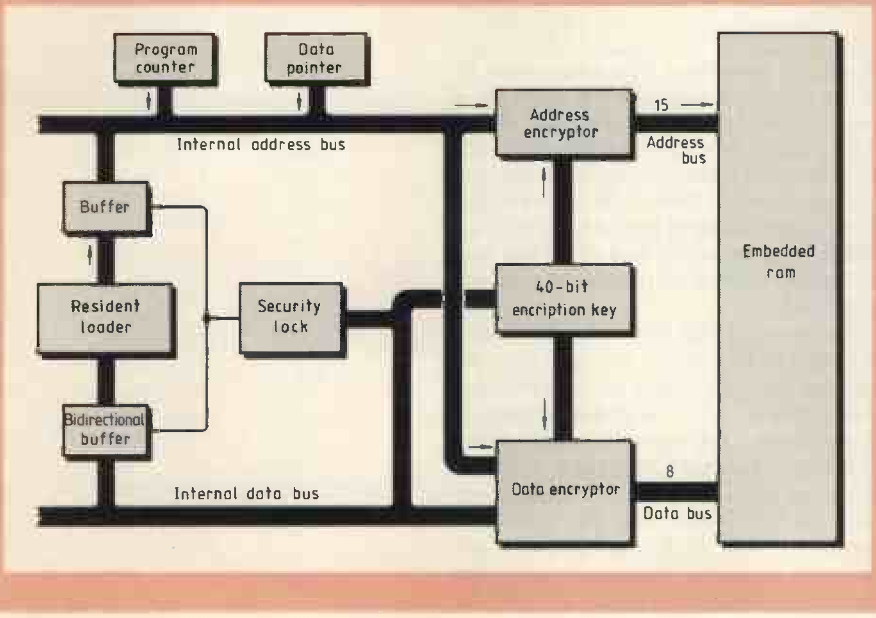
His third article describes a partial instruction set and corresponding microcode for the demonstration processor presented in the January issue.

Soft microcontroller development system

The DS5000 'soft' microcontroller has the same pin configuration and instruction set as the 8051 microcontroller, but it also has a 32Kbyte non-volatile ram, a data-encryption unit, power-down circuits and a lithium battery. Despite these additional features, it is still easier to design with in hardware terms than the 8051.

Development of the 5000 can be carried out through a small module that plugs into an 8051-type socket at one end and a serial port to the host computer at the other. Software written using standard 8051 development tools is sent to the module down the serial link and may be modified at will; because the program memory of the 5000 is non-volatile ram, there is no need for extra erasing hardware. Once at the module, the 8051-like software enters the 5000 and the programming is done.

If an IBM PC-compatible computer is used to design the software, development is further simplified. Disc routines supplied with the DS5000 evaluation kit provide a high-level interface between the software writer and the device so the programmer doesn't even need to know how the 5000's serial-loading mode works.



Information about the Dallas Semiconductor DS5000 and its evaluation kit can be obtained by ringing 021 745 8252 in the UK or 214 450 0400 in USA.

DS5000

As yet, microcontroller chips contain only small amounts of ram, but the DS5000 8051-like controller has 32Kbyte of non-volatile memory. Admittedly, this memory is not part of the microcontroller chip but, since the 5000's pinning and instruction set match those of the 8051, where the ram is physically positioned doesn't matter provided that economy in the final design is not an overriding factor.

Besides memory and a controller, the 5000 module holds a lithium battery, power-down circuits and a data-encryption unit for software protection. During power failures or interruptions, all memory and controller registers are automatically protected for up to 10 years.

Because the 5000's ram is non-volatile, there is no need to program roms or eproms; programmable registers divide the memory space into program and data areas. Programmable registers also determine the controller's 40bit data-encryption code and power-control/watchdog-timer modes.

Once software is created using 8051 development tools, programming of the 5000 is done through a serial or parallel interface. In parallel mode, the 5000 emulates the 8751 so that an eprom programmer can be used and in serial mode it is simply fed with data through an RS232 link.

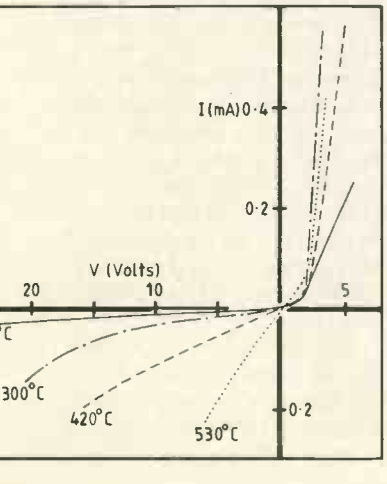
RESEARCH NOTES

thin film of cobalt was first deposited on to a smooth substrate. A circular track pattern was then defined on the disc by an electron beam on an electron-sensitive photoresist layer. The exposed photoresist was removed by developing. Etching removed the magnetic material between resist-defined tracks, leaving physically discrete tracks of cobalt alloy. Tracks were 200 microns apart, so that conventional recording heads could be used for reading and writing data.

Obviously, before it can become practical for a 3.5inch disc to store 10^{10} bits of data, there will have to be vast improvements in recording heads and disc-drive technology. Nevertheless this work does seem to show that magnetic disc technology still has room for development.

Semiconductors: some like it hot

Those of us brought up on valve technology have clear memories of the early germanium transistors – one whiff of a soldering iron and they were dead! Since then, of course, silicon technology has made life somewhat easier from the point of view of circuit assembly. But there are many environments today where it would be a great advantage to have semiconductors capable of working at temperatures well in excess of 200°C. Engine monitoring devices and spacecraft are just two examples that come to mind.



A significant step towards high temperature devices has been made by a team of Japanese physicists working at the National Institute for Research in Inorganic Materials at Ibaraki. Using what they describe (*Science* vol. 238 p. 181) as a temperature difference solvent method, they have successfully fabricated a p-n junction diode from boron nitride that functions to a temperature of 530°C. Boron nitride, the simplest III-V compound, has the widest energy gap (>6.4eV) and remains stable up to 1300°C.

Cubic boron nitride is a transparent diamond-like material made by putting the common hexagonal form under intense pressure (55 kilobars) at high temperatures (1700°C). The cubic form is then heated again under similar conditions with a lithium calcium boron nitride solvent to which about 1% of beryllium metal is added. Dark blue crystals of p-type boron nitride separate out. These p-type crystals are then treated yet again in similar fashion, but using a solvent containing 5% silicon. This creates an n-type boron nitride layer which crystallizes on top of the p-type material.

Two of these composite crystals were cut into slabs and ground with a diamond wheel to expose a surface on which contacts could be fitted. Since there is no way of making permanent ohmic contacts, pointed probes were used instead. Test results shown below, left, demonstrate that unidirectional properties are maintained up to about 600°C, though the Japanese researchers say that an ideal boron nitride diode should operate up to 1300°C, the temperature at which the material becomes thermally unstable.

The source of the reverse leakage current at high temperatures is not yet precisely understood, but the researchers say that the performance of the diodes might be improved in this respect by the use of more refined materials. Given such refinements they believe that cubic boron nitride holds out real promise of a range of practical high temperature semiconductor devices. As well as possessing a large energy gap the material also has a low dielectric constant and a high thermal conductivity. The only real remaining problem is how to fit permanent ohmic contacts with less than about 1MΩ contact resistance.

When that problem is solved we may then end up with semiconductors that will work at temperatures well above those at which valves being to melt!

How Russians stimulate their birds

Observations in last month's *Research Notes* on what birds do when they perch on overhead power lines are not likely to raise even a flicker of a smile among engineers working for Nippon Telephone and Telegraph. Migratory flocks are apparently soiling the surfaces of dish antennae during enforced stopovers. Doves and sparrows make their nests in the antenna frames, while crows peck at the wires, causing short circuits. But before Japan's whole telecommunications infrastructure grinds to a halt under the weight of the avian invasion, help may be at hand from an unusual quarter.

In a rare and touching example of *glasnost*, Soviet researchers have revealed a novel way to keep the engineers happy, whilst at the same time sparing our feathered friends from chemical extermination.

Researchers at the Severtsev Institute of Evolutionary Morphology and Ecology of Animals, the Lithuanian Academy of Sciences and Moscow University have developed a new type of bioacoustic stimulator (*sic*) which, according to the Novosti Press Agency, is effective in influencing birds' behaviour. A sort of electronic request to use the proper facilities?

Admitting frankly that the scientific and technological revolution has "complicated the relationship between man and birds", the Russians report brief details of a second-generation stimulator. What it does is imitate some of the bird sounds that the feathered variety find particularly uncomfortable, such as alarm calls. But the ingenuity of this Mk2 machine doesn't stop there.

In what sounds remarkably like a spin-off from Star Wars research, the Russian bird scarer – sorry, bioacoustic stimulator – makes use of moving light beams to get the birds off their perches. But does it work? Novosti claims that the idea has been tested in a sweet cherry plantation and that about 1.5 tons of cherries per hectare were saved.

Superconductivity paper chase

When a field of endeavour advances at the rate currently being experienced in superconductivity, some interesting things happen to the normally sedate process of scientific publishing. Researchers are no longer willing or able to wait for the days, weeks or months it can take for the latest journals to arrive. In the hope of gaining an edge they are relying increasingly on informal means of communications such as the telephone or on advance drafts of unpublished papers. Computerized listings of such unpublished papers are now becoming increasingly available.

However, scepticism surrounds all aspects of high-temperature superconductivity. No sooner does someone claim to have discovered a compound that loses all resistance at room temperature than someone else debunks the claim. In the last few months there have been several such claims, nearly all of which have proved either unrepeatable or which relate to some exotic phase of an inherently unstable material. Whatever happens in the next few months in the world's laboratories, one thing is clear: room temperature superconductivity is no subject to start writing a text book about.

Research Notes is written by John Wilson.

RESEARCH NOTES

Biggest antenna in the universe

Readers working on high-gain antenna systems may be interested to know that the largest collecting mechanism in the universe is not at Jodrell Bank or Arecibo, or even in the possession of extra-terrestrial intelligence. It's actually several orders of magnitude better in terms of resolving power and has a gain of 100 000 at radio wavelengths. Still guessing? The antenna in question is nothing man-made at all, but a whole galaxy floating in space: in fact, many of them.

A galaxy, being a large cluster of stars, has associated with it powerful gravitational fields. These fields have the property of bending any passing radiation in much the same way as a lens refracts rays of light. About 15 years ago this theoretical prediction was verified by the discovery of 'pairs' of stars which, because of their properties, were later shown to be single stars. What was happening was that the light rays from these stars were entering different parts of a gravitational lens and merging in slightly different directions, hence producing two or more images as seen from earth.

Obviously that situation corresponds to an optical system that is out of focus and it provides little advantage for an astronomer who merely sees double. The interesting question is whether, by good luck, it might be ever possible for some distant object to form a single sharply focussed and highly magnified image here on earth.

A paper in *Nature* vol.330 no.6146 from the physics department of University College, Dublin and the astrophysics division of the sciences department of Estec in the Netherlands addresses the theory behind such speculation. The conclusion appears to be that an elliptical galaxy creates not a sharply focussed point image, but a series of so-called caustics like the bright curves on the surface of a brightly illuminated cup of tea. Doctors B. McBreen and L. Metcalfe calculate the extent to which such 'optics' intensify a point-source such as a distant star at the edge of the Universe. The answer, as with a man-made telescope or radio dish, is dependent on wavelength. The shorter the wavelength the greater the gain and the greater the angular resolution.

In the case of a typical galactic 'lens', the gain at radio wavelengths will be approximately 10^5 increasing to 10^8 at X-ray wavelengths. The beam width at X-rays is correspondingly narrow, of the order of 10^{-17} arc second.

On the basis of this theory it should be possible under favourable conditions to observe an object no bigger than a few kilometres across at the very edge of the universe. Of course, without an astronomical antenna rotator, there are strict limits on the practicability of such a giant system! Nevertheless the universe is far from static and there are many interesting phenomena that may well drift into the areas of maximum intensification as observed from earth. Core regions of quasars, active galactic nuclei and other objects associated with black holes are a few suggested possibilities.

Experiments with cosmic time

If the cosmos contains the biggest-ever telescope, it may also contain the most accurate clock. But reviving the idea of astronomical time standards may seem rather odd after their relatively recent demise in favour of atomic standards. Only in 1967 was Greenwich Mean Time, based on the Earth's motion, abandoned in favour of Universal Coordinated Time (UTC), based on resonances in the caesium atom. GMT when compared to UTC varies up to a second per year, due to perturbations in the earth's movement. To keep broadcast UTC time-signals in step with the earth, one pip is added or subtracted in the form of a leap second by the international standards bureaux.

But if the earth is a bad timekeeper because of irregularities in its motion, the same is not necessarily true of more distant astronomical objects. Pulsars, those flashing rotating stars discovered at radio wavelengths in 1967 at Cambridge, have a pulse repetition rate accurate to one part in 10^{12} over a time scale of a few years. But conventional pulsars with a period around one second are relatively young and hence unstable objects, no more precise as timekeepers than relatively cheap atomic standards.

What has excited astronomers in recent years is the discovery of very fast pulsars, the so-called millisecond pulsars. Four of these puzzling objects have so far been discovered, which emit bursts of radiation at a pulse repetition rate of 1kHz or more. Not only does this presuppose a prodigious rate of spin, it also seems to make for a very high degree of stability.

Observations of radio emissions at 1408MHz and 2380MHz by physicists at Princeton University, New Jersey, and at the Arecibo Observatory at Puerto Rico suggest that millisecond pulsars may have a frequency stability at least as good as one part in 6×10^{14} when averaged over a four-month period. Over longer periods still, the measurements are limited by the accuracy of the reference atomic clocks, which are locked to international standards by satellite.

Whether or not long-term pulsar observations will ever be used to correct our present-day caesium and rubidium time standards is a moot point. But knowing that the fast-spinning pulsars have a high long-term stability opens the way to some interesting experiments on radio propagation.

Writing in *Science* vol. 238 p. 761, the Princeton group reports its observations of radio waves arriving from pulsar PSR 1937 + 21. Short-term instabilities in the arrival time of the radio waves are not due to the pulsar itself, but to modulation of the emissions as they travel between the pulsar and earth. The source of this modulation, according to some cosmological theories, is a form of interstellar energy known as gravitational radiation. If a gravity wave were to pass through the pulsar or through the earth, it would cause a change in the timing of any radio pulse travelling between them.

Distinguishing the effects of gravitational radiation from other perturbations is a difficult task (to say the least!) but the American researchers believe they can now use these measurements to place a firm upper limit on the energy density of such radiation. The quantity in question, 7×10^{-36}g/cm^3, may not seem much, but to cosmologists grappling with the future expansion of the Universe it is an extremely useful piece of new data. It may make all the difference between whether the universe goes on expanding for ever or ends up in a Big Crunch.

Denser discs

Scientists at IBM's Almaden Research Centre have produced experimental magnetic discs with tracks half a micron wide. At such dimensions, the 3.5inch diameter discs used in computer storage could each hold 10^{10} bits of information — 50 times more than today's densest disc.

In magnetic discs information is recorded as 'bit cells', tiny magnetized regions along the tracks. The group claims to have recorded, read and erased bit cells measuring 0.5 by 0.5 microns.

The scientists discovered also that the magnetic regions in these narrow tracks behave in a similar way to the much larger regions in today's discs. For example, the fundamental process of reading the recorded information can be carried out in a predictable manner down to sub-micron bit-cell dimensions. They also learned that magnetic interactions within such small cells enable even higher storage densities than originally anticipated.

The sub-micron tracks were formed by etching the surface of the disc with photolithographic techniques similar to those used in semiconductor processing. A

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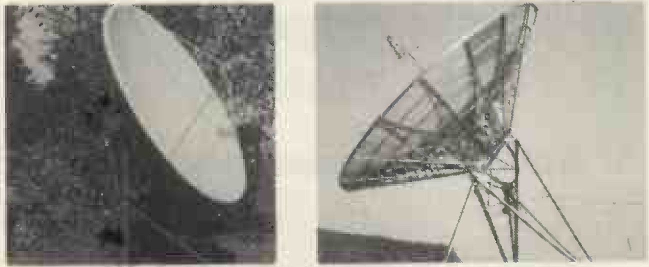

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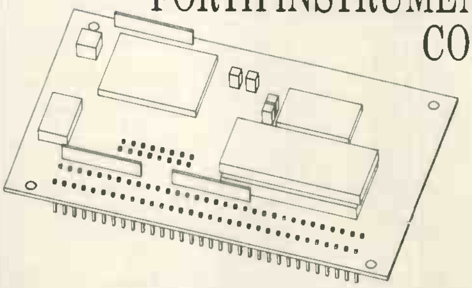

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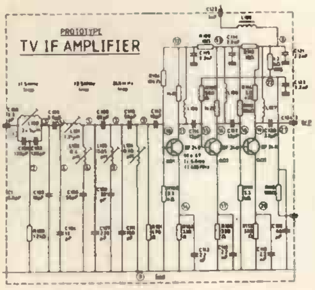
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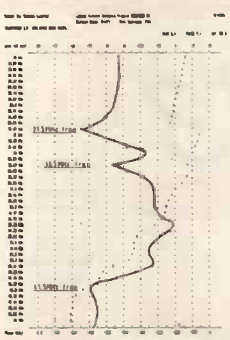

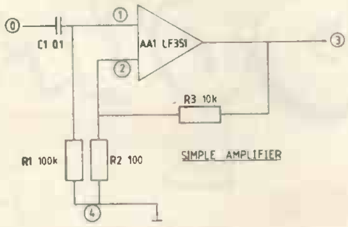
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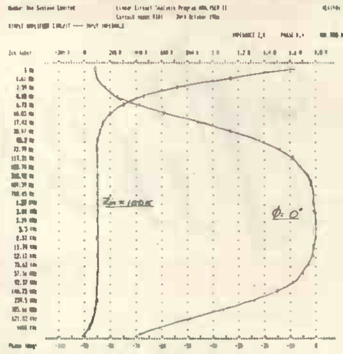
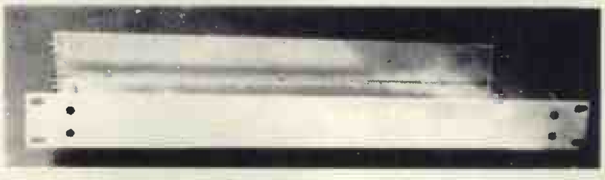




Pioneers

15. William Shockley, John Bardeen and Walter Brattain: inventors of the transistor.

W.A. ATHERTON

The three inventors: Shockley seated, Bardeen standing left, Brattain standing right (Bell Laboratories – AT&T).

The forerunner of today's ubiquitous silicon chip was the point-contact transistor made by John Bardeen and Walter Brattain at Bell Laboratories in America in December 1947. It was followed by the junction transistor conceived about a month later by William Shockley, also at Bell Labs, and first made in 1950.

By some, the transistor has been hailed as the most important invention of the 20th century. It is a dangerous claim because, to some extent, we all suffer from professional and chronological snobbery. Fifty years ago, electronics engineers would have included the triode in a list of the most important inventions. Fifty years from now the transistor may be a passing memory. But for now, as electronics continues its invasion in most walks of life, it is difficult to see how we could manage without the transistor in its many forms.

The importance of the transistor was officially recognized when the three were awarded the Nobel Prize for Physics in 1956. John Bardeen, by then professor of electrical engineering and physics at the University of Illinois, had no idea they were even being considered for the prize and was stunned when he heard of the award – on the 7.15 a.m. news bulletin. Sixteen years later he was awoken by an early morning telephone call from Sweden to be told that he was the first person ever to be awarded a second Nobel Prize in the same field, this time for his work with L.N. Cooper and J.R. Schrieffer on the theory of superconductivity.

On that day in 1972, the Bardeen telephone was swamped with incoming calls and was taken off the hook so that breakfast could be eaten in peace. When Bardeen came to leave home his departure was delayed by a fault in his transistorized garage door opener. The story grew that on the day he won his second Nobel Prize the inventor of the transistor could not get out of his garage because of a faulty transistor. A good story: but, as John Bardeen points out, the problem lay with a faulty switch, not a blown transistor.

SEMICONDUCTORS

The foundations of solid-state physics, and hence semiconductor theory, were laid between about 1925 and 1933 mainly in Europe where physicists used the new quantum mechanics to develop an understanding of electrical conduction in solids.

Then came the Second World War and the immense effort to develop and improve radar. Interest revived in the by then obsolete crystal or cat's whisker (point-contact) diodes which could operate at higher frequencies than the available valve diodes. Germanium and silicon came to the fore in preference to materials such as copper oxide because, as elements, their understanding and processing was expected to be simpler.

Teams of physicists, chemists and metallurgists were brought together and materials and theories were improved. In 1941 R.S. Ohl at Bell Laboratories found that the rectifying properties of a p-n junction were excellent as had in fact been predicted in 1938 by B. Davidov in Russia.

By the end of the war some researchers recognised that further work might pay off with practical devices. In July 1945 Bell Labs set up a solid-state research programme. The official authorization for the work stated the purpose as obtaining "new knowledge that can be used in development of completely new and improved components and apparatus elements of communication systems". A sub-group, the semiconductor group, discovered the transistor effect three years later.

ASSEMBLING THE CAST: BRATTAIN

Of the three inventors, the oldest, and the first to join Bell Labs, was Walter Houser Brattain. He was born of American parents on 10 February, 1902, in Amoy, China, where his father was a teacher in a private school. The family returned to the USA and Brattain grew up in Washington State. Early on he demonstrated an aptitude for mechnical tinkering and at high school he even volunteered to maintain the diesel engine which powered the school lights. His experimental talents were the perfect complement to Bardeen's and Shockley's theoretical gifts.

This experimental aptitude was strongly reinforced when he took his physics degree at Whitman College in Washington State, where his professor maintained that once something was written down "it has become a fossil". It was to Whitman that Brattain returned as Visiting Professor when he retired from Bell in 1967. He died last October, aged 85.

Brattain gained his Ph.D. at the University of Minnesota in 1929. His supervisor, John Tate, had studied in Berlin under Heinrich Hertz. At that time in the United States only a handful of leading physicists were immersed in solid-state physics and quantum mechanics. One of them was John Van Vleck at Minnesota, and from him Brattain learned quantum mechanics. Later when Van Vleck was at the University of Wisconsin he also taught quantum mechanics to Bardeen!

After receiving his doctorate Brattain failed in a bid to join Bell Labs and settled for a job in the radio section of the National Bureau of Standards, earning about $50 a week. He was not there long before he was accepted by Bell at the second attempt. Within a couple of years he was studying copper oxide semiconductor rectifiers. He stayed at Bell until his retirement in 1967 except for a spell during the war when he was at Columbia University working on submarine detection.

SHOCKLEY

The second of the trio to join Bell Labs was William Shockley, the only one of the three to join straight from university. Like Brattain, he was born of American parents in a foreign land – in London on 13 February, 1910, almost eight years to the day after Brattain's birth.

When he was aged three, the Shockleys returned to the US and settled near San Francisco in the Santa Clara valley. In 1955, with the aid of Beckman Instruments, William Shockley set up the Shockley Semiconductor Laboratories in his home town of Palo Alto. It was the first semiconductor company in what is now Silicon Valley.

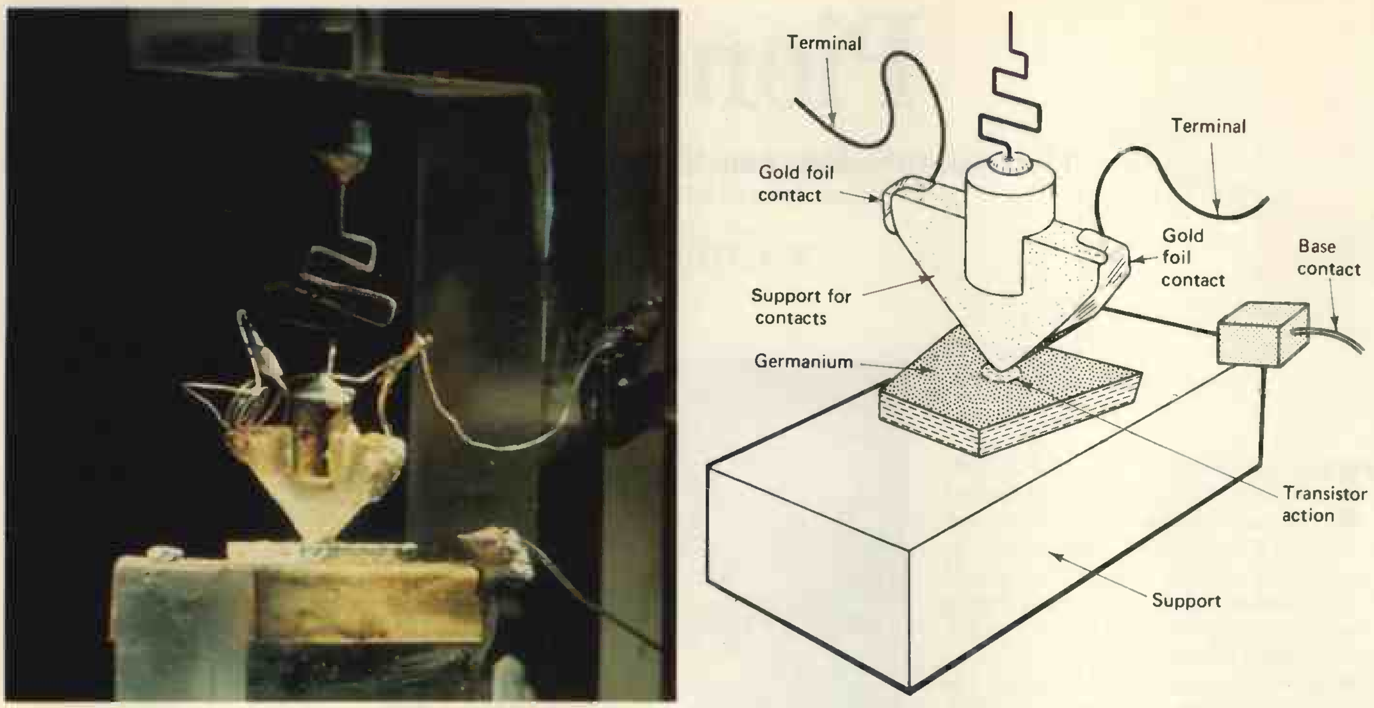


Fig.2. The first point-contact transistor, 16 December, 1947 (photograph by courtesy of Bell Laboratories).

His reputation attracted a number of the relatively few semiconductor experts around to join him. The company changed to manufacturing and was renamed Shockley Transistor but the factory eventually closed in 1969. In 1957 however, eight of those who had joined Shockley left to form their own company – Fairchild Semiconductor. In turn Fairchild employees left to form a whole string of other companies in what was almost a chain reaction. Tongue in cheek, one could say that William Shockley founded Silicon Valley and based it on his home town.

Since 1963 Shockley has been a professor at Stanford University but he was educated at the California Institute of Technology and took a Ph.D. in semiconductor physics at the Massachusetts Institute of Technology in 1936. He was immediately attracted to Bell Labs where he was assigned to work under C.J. Davisson who, with L. Germer, won the Nobel Prize for their 1925 work on electron diffraction. Shockley was loaned to another section to work on valve research but, three years later, he paired up with Brattain to try to make a semiconductor triode – in 1939.

The similarities between semiconductor and vacuum diodes had led several people to speculate on the possibilities of putting a 'grid' into a crystal to make a crystal triode. J.E. Lilienfeld filed for American patents in the 1920s and O. Heil for a British patent for what would now be called an insulated-gate fet in 1935. Neither had the technology to make a workable device. In 1938 R. Hilsch and R.W. Pohl gave a scientific demonstration of a working crystal triode using potassium bromide. but it was not something which could be developed into a useful amplifier.

On joining Bell, Shockley had been inspired by Dr Mervin Kelly, the director of research, with the dream of replacing mechanical telephone exchange switches with electronic switches. "He stressed its importance to me so vividly that it made an indelible impression," Shockley recalled[1]. That impression helped to drive Shockley's future work.

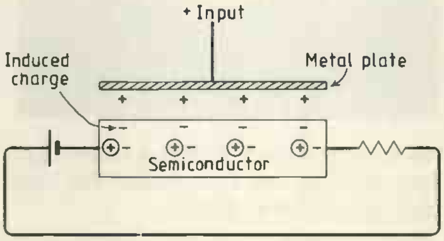


Fig.1 Shockley's idea for a solid-state field-effect amplifier in which a signal applied at the input would modulate the surface conductance of the semiconductor (1945). The experiments were unsuccessful.

On 29 December, 1939, Shockley's notebook records what he now sees as his first milestone on the way to the transistor, his ideas for what would now be called a Schottky-gate fet made from copper oxide. It was this that he and Brattain tried, and failed, to make early in 1940. In fact both men had separately rejected even earlier ideas. These were the first of what Shockley has come to call "creative failures."

The war took Shockley and Brattain away from Bell to work separately on anti-submarine warfare. Shockley was awarded the Order of Merit for his work on bomber radars.

After the war, it was back to Bell Labs where in 1945 Mervin Kelly signed the authorization mentioned above for the research to develop new components. Shockley headed the semiconductor sub-group which now included Brattain, Gerald Pearson (a physicist), Robert Gibney (a physical chemist) and a new recruit to Bell Labs whom Shockley had persuaded to join – John Bardeen.

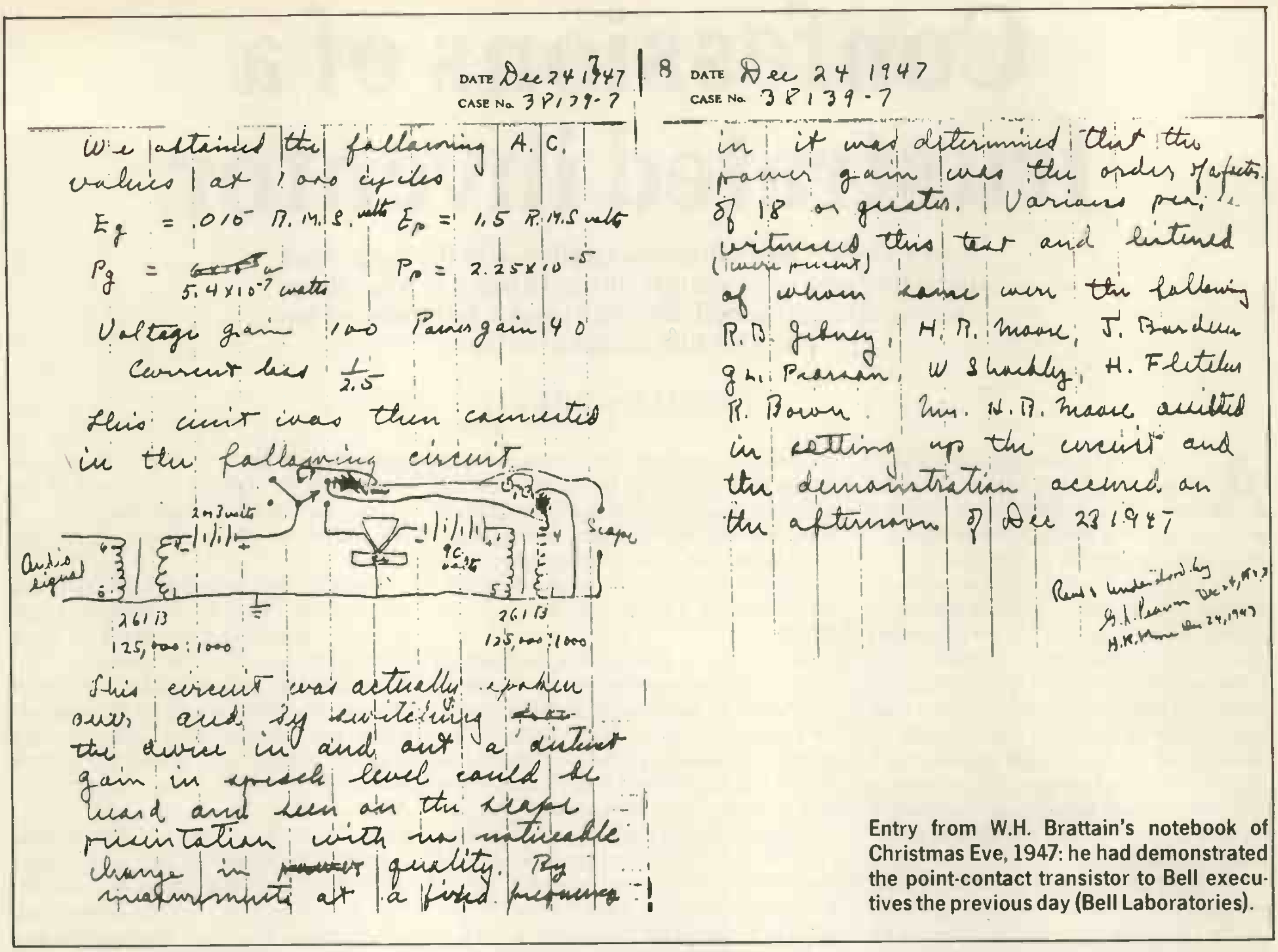
BARDEEN

Unlike the other two Bardeen was actually born in the United States, at Madison, Wisconsin, on 23 May, 1908. He will be eighty this year. His schooling was at Madison (where he hated English) and he received a bachelor's degree in electrical engineering (1928) and a master's degree (1929) from the University of Wisconsin where his father was a teacher in the medical school.

Since 1951 Bardeen has been a professor at the University of Illinois, where he retired with the status of Emeritus Professor in 1975. But his early career was one of movement. He began as a geophysicist with Gulf Oil in Pittsburgh, a far cry from semiconductors, but after three years he enrolled at Princeton for a Ph.D. in mathematical physics. It was this which introduced him to solid-state theory. After a fellowship at Harvard he took a teaching position at the University of Minnesota. During the war he went to the Naval Ordnance Laboratory in Washington, D.C., where he stayed until Shockley tempted him into the newly-formed solid-state group at Bell Labs in autumn 1945.

By then Shockley was again thinking of ways to make a solid-state amplifier. His main idea was for a field-effect device made from a thin layer of semiconductor and a sheet of metal arranged together as a parallel plate capacitor (Fig.1). A voltage applied to one plate, the metal, would induce charge on the other plate, the semiconductor, and so control the conductance of the semiconductor. A signal applied to the metal should modulate a current flowing through the semiconductor and so provide an amplifier.

The theory was fine and is the basis of today's mos field-effect transistors, but for Shockley in 1945 the device just did not work. The induced charge in the semicon-



DATE Dec 24 1947
CASE No. 38139-7

We obtained the following A.C. values at 1000 cycles

E_g = .015 R.M.S. volts E_p = 1.5 R.M.S volts

P_g = ~~[illegible]~~ 5.4×10⁻⁷ watts P_p = 2.25×10⁻⁵

Voltage gain 100 Power gain 40

Current loss $\frac{1}{2.5}$

This circuit was then connected in the following circuit

This circuit was actually spoken over and by switching ~~[illegible]~~ the device in and out a distinct gain in speech level could be heard and seen on the scope presentation with no noticeable change in ~~power~~ quality. By measurements at a fixed frequency

8 DATE Dec 24 1947
CASE No. 38139-7

in it was determined that the power gain was the order of a factor of 18 or greater. Various people witnessed this test and listened (were present) of whom some were the following R.B. Gibney, H.R. Moore, J. Bardeen, G.L. Pearson, W Shockley, H. Fletcher R. Bown. Mr. H.R. Moore assisted in setting up the circuit and the demonstration occurred on the afternoon of Dec 23 1947

Read & understood by
G.L. Pearson Dec 24, 1947
H.R. Moore Dec 24, 1947

Entry from W.H. Brattain's notebook of Christmas Eve, 1947: he had demonstrated the point-contact transistor to Bell executives the previous day (Bell Laboratories).

ductor 'plate' was apparently not there. He calculated that the effect achieved was some 1500 times smaller than his theory predicted. Bardeen checked the calculations and two weeks later there were two puzzled physicists instead of one.

But nine months later, on 19 March, 1946, Bardeen cracked the puzzle with what Shockley has described as "one of the most significant research ideas of the semiconductor program". The induced charge was there after all, suggested Bardeen, but it was thoroughly trapped by the conditions at the surface of the semiconductor, trapped by "surface states". The induced charge was immobile, unable to do the job Shockley had appointed for it.

This concept of surface states became a central part of the research effort. Meanwhile Shockley proposed a lightning arrestor made from alternate layers of a n- and p-type silicon. It was the first of a number of occasions when he came close to the idea of the junction transistor, only to turn away. But he was unravelling p-n junction theory.

Late in June a two-month interlude began for Shockley and Bardeen when they left for a trip to Europe to attend a conference in Bristol and visit major research centres throughout Europe. The list of the people they met reads like a Who's Who of physics. Accommodation was sometimes a problem, though, as Bardeen has recounted. In Amsterdam only one room was available – and it had a double bed! It is amusing to think of these two great scientists sharing a bed with their heads at opposite ends.

THE TRANSISTOR

In September, back at Bell Labs, Shockley studied the theory of how an n-p-n structure could be used as a negative resistance thermistor. Again he was close, but not close enough, to the junction transistor.

Then in November, whilst studying photovoltages, Brattain and Gibney (the physical chemist of the group) overcame the blocking effects of the surface states by immersing the semiconductor and the metal plate in an electrolyte. This galvanized the group into intense action. Suddenly the field-effect crystal triode seemed realisable.

An electrolyte device gave some amplification at very low frequencies. Bardeen and Brattain tried to improve matters by evaporating a gold spot on to the surface of n-type germanium. To their surprise they found that a positive bias injected holes from the spot into the germanium, so changing its conductivity without any use of the field effect at all. A point contact placed close to the gold spot collected the hole current. The transistor effect had been observed but was too feeble to offer amplification.

They soon worked out that two point contacts placed about 0.05mm apart should succeed. How to do that was a problem, but it was solved by evaporating gold on to a polystyrene wedge and separating the gold at the point of the wedge by cutting with a razor blade. The point-contact transistor was born and, after all the efforts to produce a field-effect device, it was the bipolar transistor that had unexpectedly been found.

According to Shockley[1] the date was 16 December, 1947. It is usually stated that the transistor was invented on 23 December, but that was the day when the device was demonstrated to executives at Bell. The public announcement did not come until 1 July, 1948.

The discovery of bipolar transistor action was a magnificent Christmas present and the members of the group were elated. William Shockley admits to an understandable feeling of frustration that, after all his efforts, he had not played a significant part in the invention. On 20 January, however, he announced his ideas for replacing the point contacts with p-n junctions – the conception of the junction transistor. It was not just an idea, he had worked out the theory as well which he included in a book published in 1950, a year before the first reliable junction transistor was made.

Once junction transistors were produced commercially the point-contact device became obsolete.

References

1. W. Shockley, The path to the conception of the junction transistor, *IEEE Trans. ED-23.* 597-620, July 1976.

See also: E. Braun & S. MacDonald, Revolution in miniature, Cambridge University Press 1978, and J. Bardeen, *Science*, November 1984.

Next in this series of pioneers of electrical communication: Charles Kao – father of fibre optic cables.

Confessions of a frustrated inventor

Most technical journalists are familiar with the "aggrieved inventor" who can persuade no one to listen to him. Many can be written off as self-deluding cranks, but there are too many for that always to be true.

HEINZ LIPSCHUTZ

About two years have now passed since the late R.E. Young's series of articles appeared in *Electronics & Wireless World*, describing Britain's hidden strength in the field of invention and electronics.

To this could be added, with much justification, the generally accepted high standard of engineers, which I for one never doubted, even when my life depended upon it during the many years I spent flying as an airline captain, on aircraft designed, built and maintained in Britain – which never let me down; or the earlier years spent among a highly professional group of civil servants in the Civil Aviation Department (attached to the RAF during the war) and later in broadcast engineering.

However, after reading the series, I could not put my finger on any point in the articles which explained the existing discrepancy between the obvious potential and the equally obvious lack of translation of this potential into something like the recent 100 billion dollars trade surplus that the Japanese managed to achieve – even without North Sea oil. Granted that the ability and the means exist, why the long list of failures as depicted in the pictures from the Engineering Council and reproduced in the final article – a list which is by no means complete and to which could be added pages full of missed opportunities, some of which are known but also many which have never been published and thus are unknown to the public.

Having been personally involved in 1939 with one such missed major opportunity and the serious consequences which followed, I have since then devoted a greater part of my life to studying the causes, and inquiring into the hidden motivation that controls the often counter-productive and highly dangerous actions of so many people. After more than 40 years of double-checking the accuracy of my observations, I now feel reasonably sure I can rely upon the conclusions reached. These are chiefly based upon first-hand experience, not hearsay, and are as free from personal wishful thinking and environmental influences as I could make them, since originally my interest had been limited to discovering the causes just for my own satisfaction, as free from errors as possible; and I had no intention of getting involved, or publishing my findings for any other reason.

On the whole, I have kept my opinions to myself, because it has become quite clear to me that there is very little hope of changing or even just slightly influencing the outcome. Thus, I normally kept all the results of a lifetime of independent R & D work secret, especially the big successes, having found early in life that to be called an 'inventor' is synonymous with being considered a crank, and occupying a status next in line to the village idiot.

Nevertheless I decided, ten years ago, in spite of my earlier bad experience, to have a second try, for two reasons. Firstly, because, on a personal level, I had met so many nice people who deserved some contribution by myself towards a better future for everyone and secondly, I was curious what the outcome would be if I persevered for at least ten years. By highlighting in this report some of the obstructions to progress faced by anyone trying to advance technology here in Britain with a fundamental invention, it is just possible that a change towards a less hostile attitude may occur. However, since the treatment of inventors throughout history was well known to me even while still in school, I was under no illusions. Hence when I decided to come forward with a major and fundamental invention – that first time in 1939, at the beginning of World War 2 – when Britain was in difficulties, I did so only because I felt some obligation to contribute.

Aware of the fact that the RAF was virtually blind when navigating over Germany and in urgent need of a system which could not be jammed, I tried to give to the British Government the design of what is now known as 'INS' i.e. 'Inertial Navigation System', with yearly sales presently said to exceed a value of one billion dollars (mostly in favour of USA firms such as Litton Industries Inc.) and serving as the backbone of all military aviation, missile guidance and spacecraft.

My free offer to the British Government in 1939, presented as an 'Automatic Position Indication System', was rejected in the most patronizing way, preventing me from even getting to the stage of a dialogue. I was not annoyed, but quite surprised, since my intention had been to follow-up my offer with several others.

To a number of people it was quite well-known during the war that, due to the lack of precise navigation equipment, the effectiveness of the RAF's bombing raids was much reduced, and the hoped-for damage to the German war effort and hence an early victory was not achieved. As a result, many more British soldiers (and civilians) died needlessly, or suffered in German p.o.w. camps. Also, probably a million inmates of concentration camps might have been saved.

Much of this navigation problem was reported on Radio 4, in April 1978, and thereafter printed in *The Listener* of 7 April, from which, herewith a few quotes.

Page 423. *Cherwell– a civilian member of the cabinet office, analysed 600 photographs taken by crews which claimed to have reached the target area. It was clear that the average crew could not find, let alone destroy a small target.*

Page 426. *By the summer of 1943, neither precision attacks, like the dams raid, nor the relentless destruction of whole cities had had any visible effect on the German war effort; indeed, as we now know, production during this period actually increased.*

INS was later re-invented, built by Professor Draper of MIT in the US, and test-flown for the first time in 1956, eleven years too late to be of use during the war. Ever since, the USA has cashed in on the fact that most of the patents are held there, with royalties paid by all others, including Britain.

After the war I generally avoided arguments about inventions, although in 1957, again in 1960 and 1962, I gave some support to several acquaintances of mine who tried, with the help of some of their MPs and also Air Vice Marshal Bennett, to interest the British Navy in the 'U-Plane' (short for 'Undersea-Plane'), i.e. the application of the principle of flight (as in the air) to craft operating below water. As this permits the construction of submersibles which are heavier than the water displaced, with the missing buoyancy replaced by lift from a small wing – a trick known to several kinds of shark for several million years – such a craft can be constructed with a crew module which is exceedingly strong and so permits descent to the deepest bottom of any ocean. When published as a general suggestion in the letter pages of *New Scientist* in 1960, Vickers' comment – published a week later – was that 'present-day' submarines are already able to descend 'as deep as is wished', using conventional design. As there is no answer to that, I shelved further effort to influence the establishment at that time.

Only after about 1977, i.e. shortly after my retirement from active flying with British Airways, was I once more tempted to try to do something in return for the good times.

However, like other people with similar intentions, I found myself enveloped in what seemed to be a gigantic sponge or black hole, into which everything I did, said or wrote disappeared without trace or response.

It might help to explain the problems facing inventors if I give hereafter just a few details which are based on first-hand experience, which is available for investigation by anyone interested enough to check up, and not second-hand hearsay. Also, in a later paragraph I will indicate other problems repeatedly met, and solutions needed to improve the whole situation.

A major problem I discovered, was the inability to get a fair hearing. The reason was a 'Catch 22' situation in that nobody wanted to know, having never before even heard of me, and that most of the media did not want to publish anything by me for the same reason, so that as a consequence nobody heard about me.

When I occasionally did succeed, as with my letter published in the magazine *Practical Hi-Fi*, December 1979, I found the subject referred to about three years later in *New Scientist* dated 13 Janauary 1983 but without mentioning my name or *Practical Hi-Fi*. In this letter I had pointed out that "In a sealed loudspeaker enclosure the load presented to the cone by the enclosed air was considerably greater during the inward movement of the cone than during the outward movement, with the difference in a small enclosure reaching 10% or more, which was thus liable to cause some degree of asymmetrical clipping". This later appeared in the *New Scientist* of 13 January 1983 as "Loudspeaker designers have only recently realised that when a speaker is mounted in a sealed cabinet, the piston movements of its diaphragm create pressure changes of up to 104dB in the trapped air. The variations present a non-linear resistance to the diaphragm's movement, which distorts the sound. Now the British loudspeaker company Goodmans has developed a clever circuit which automatically adjusts the air pressure . . . . . ". While the *New Scientist* cannot be blamed for not being aware of my letter published three years earlier, it does not help my efforts to establish a track record upon which to build a reputation.

When presenting my findings to the journal of the IERE, the 'Member of the Committee' was reported (in a letter of 7 April 1981) as stating that my "claim was based on a false premise, in that an *infinite baffle system* merely isolates front and back air pressure variations and cannot be non-linear"; totally disregarding the not unimportant fact that I had referred to a *sealed enclosure*, not an infinite baffle (which could in theory also have infinite volumes of air on each side). I never heard from them again. This was a early exact copy of the brush-off in 1939.

Also during 1979, having approached two major British loudspeaker producers with my pending patent, described in *Hi-Fi News* April 1980, and been politely informed (individually) of their disinclination to proceed, both thereafter applied for patents which looked to me very similar to my own, and both seemed to deal with the same problem, but in my opinion less successfully. Since claims were very broad and inclusive, and I also wrote to the Patent Office to alert them to this, both companies had virtually no hope of getting their patent granted. Yet, for the money they had spent, they could have had mine, as well as my know-how. Both firms are of course quite free to make their decisions as they see fit and are also entitled to disagree with me or my work; and, if preferred, even go bankrupt in the face of Japanese or Korean imports.

I realised that, if I gave such reasons as the above to explain and excuse my lack of success, it would only be taken as the gripes of a crank. I therefore decided that what was necessary was to speak from a position of strength and success when referring to such matters.

Bearing all this in mind, I decided that, in order to succeed in my intention to help local industry to overtake the advances made by other countries in the technological race, and do so by means of the active promotion of inventions (and solutions to problems) already in my possession, it was necessary to diversify my career by establishing a track record which would overcome the apparent credibility gap I found myself faced with.

U-PLANE

From a number of possible contenders I eventually chose the U-Plane, since this was the key for opening up the last frontier on this globe, i.e. Inner Space, and would create many jobs in the maritime and electronics fields, in addition to giving a head start to the Royal Navy. It also had the advantage of being based upon concepts which were readily understood, and easily demonstrated by radio-controlled models.

After pursuing the original aspects of this plan for some time (which, if I also include the earlier period from the first moment of trying to interest the Government or the media in 1957, is now thirty years) the result, after special efforts since 1977, proved a total failure. Nobody wanted to know.

Hence I then decided to apply for a patent in which I disclosed considerably more details. This decision was also due to the fact that a number of scientists in the Department of Maritime Studies at UWIST (University of Wales Institute of Science and Technology) in Cardiff had suggested that the only thing that would convince people in positions of influence and power would be collaboration in the construction of a man-carrying prototype. This would of course require disclosure of many of the advanced technological features known to me so that I could work together with the scientists of UWIST as a team.

However, after my earlier experience, I feared that, when the craft had been finished, nobody would bother to turn up to watch its performance, and it would eventually finish up, with so many other items, cluttering up my garage.

By that time I had come to the conclusion that what would be more likely to succeed was the promotion of an 'International Race to the Bottom of the Sea' so that, with the oceans of the world eventually crawling with thousands of U-Planes of foreign navies, even people here in Britain might take notice.

So, shortly after receiving a letter from the Patent Office dated 17 Dec. 1984 which revoked the demand for secrecy they had earlier imposed upon the use of my pending patent application, I decided to take the necessary steps, as by then it had become abundantly clear that nobody here in Britain showed any interest. It had also been made clear beyond a shadow of doubt by the response of the media to the various approaches by myself and several other people, that they had not the slightest interest in the subject, or any intention to inform the wider British public of it.

Till then I had always assumed, from the reactions received from some editors, expecially those in the general media who had no scientific training at all and had to rely upon the advice of 'experts', that they had been getting poor advice. Or else, that my write-up was not lucid enough to bring out the significance of the U-Plane design, in spite of the fact that my description of the craft, and later also my patent specification had been written with the average reader in mind. It began to look that, somehow, my credibility was being discredited to prevent publication in Britain of anything I submitted. This also was the opinion of my friends.. even some of my letters addressed to MPs elicited no reaction. Ten years was too long a time to accept the notion that all this was just imagination. Clearly, I was flogging a dead horse.

I now made copies of everything relating to the U-Plane, travelled to London, visited the military attaches of one country after another, and gave them all the available information, while at the same time letting it be known that they were not alone, and that the same information was also given to at least 20 other countries; thereby making it clear that everyone was in competition with everyone else. I also informed all that a patent had been applied for only in Britain, and that therefore the rest of the world was totally free to proceed and use the information disclosed in my patent specification for their own purposes. Later, after a friend had made a video-tape of a working model, I revisited most of them and submitted a copy of this, as well as some additional information written in the form of a newsletter.

In the meantime my patent claims were published by the Patent Office in March last year, and copies of the specification are thus available to anyone world-wide, with a rising number of people in many countries actively pursuing the goal of production. Whenever requested by these people I have disclosed sufficient information for them to go ahead successfully, and thus prove the significance of that design so conclusively, that even the most cynical and unwilling of people here will finally have to admit that fact.

While this information is now known throughout the world, it unfortunately is still being withheld from the public in Britain, who do not, as a rule, visit the Patent Office; they normally expect to be informed by the media of any significant new development, but are, so far, completely in the dark.

Meanwhile the race has been truly 'on' now for almost three years, while all of Britain appears to be in total ignorance.

Meanwhile, there was an interview on Radio 4, at 1 p.m., on the 7 August 1987, dealing with the British invention of the body scanner (nuclear magnetic resonance imager). During the interview it was stated by Prof. John Mullard of Aberdeen University that from the sale of the scanner by GE for about £1 million each, BTG (British Technology Group) obtained royalties for the patents of about £1,000-£2,000, and that the inventors received only £5 for every £1,000 obtained by BTG. This was said to be due to the fact that whenever the R & D is financed by BTG or the Government, they hold the patent rights, and the inventor has hardly any say in the matter. It follows therefrom, that, unless an inventor has the financial muscle and the will and time to see the project through from the idea stage to the sale of the complete and saleable product, he is better off using his time and effort growing roses for his mother-in-law on the fast lane of the M1.

Otherwise, the moment he approaches a government (or any other) organization for backing or funding, he ends up just like any employee working for somebody. Only, in this case, he has none of the usual rights of an employee, but instead has the special pleasure of having to come begging cap-in-hand to an 'examiner' who, after spending possibly all of seven minutes perusing the submitted material – which, in my case of the U-Plane is based upon something like 70 thousand man hours of R & D – will then pronounce his verdict on whether they are interested in backing the project or not.

There are a number of other hurdles to overcome.

Most developments of major importance and value usually include a substantial number of sub-inventions, which preferably are all patented individually. The act of writing the patent applications and dealing with all the details associated with this work, is in itself a full-time job.

If he is in fact employed by a firm or Government department, then normally all inventions of the inventor are the property of the firm, government or whosoever funds the bill of his R & D or other expenses. If his employment is in any defence industry, or funded by the MOD, then, due to the secrecy surrounding his work, nobody may ever know of his work. Nor can he complain when treated as nothing more than a number.

If the invention has military potential, then MOD scientists may be working on similar R & D in good faith; in which case, due to secrecy all around, there may be costly duplication of effort and loss of time.

If as a result of all these reasons a valuable and important invention is lost to Britain, one reply often given by those holding the money strings is the fact that, according to them, most inventions presented to them are worthless, only 1 in ten is any good, so that any misjudgement leading to a loss of a good invention is understandable and pardonable. If the same degree of complacency was applied to the search for diamonds when there are thousands of grains of sand to every diamond found, then diamonds would be an unknown substance.

It is a self-evident fact that the general media has for many years treated inventors with ridicule and derision, and they have been so successful that nobody even notices any more the condescending and dismissive way an inventor's efforts are often reported, expecially when no great sums of money changed hands.

Thus a life-time of work resulting in new technology is, if reported at all, regularly described as just an 'idea', as if what was involved was nothing more than the result of a moment's inspiration, a lucky accident, requiring neither brains, thought or effort, and hence not deserving more than a pat on the back. For this reason the 'idea' will also arouse immediate doubt as to its usefulness and practicality, especially if it differs in any way from the conventional wisdom as it is known to the media person who, in most cases, is not only totally untrained in science, but often may also not have the intellectual equipment to be in the same league as the inventor. This breeds immediately an atmosphere of tension. Additionally, he has to write in such a way that it can be readily understood by the greatest number of readers, which means adjusting standards to the lowest common denominator. By this time the story often bears no semblance to the actual facts.

What may have been the result of ten or more years of strenuous work is thus, by the simple act of calling it an 'idea', at once denigrated by the media to the equivalent of an unplanned product of one's mind. And, being unable to correctly judge the value and significance of the invention, they therefore feel more secure when basing their judgement solely upon the money made from it, and the professional status of the inventor.

It is surely a great loss to all if a capable inventor is ignored precisely because he sticks to what he does best, until he finally either avoids disclosing anything at all and chooses another career, or gives his invention free to any competing nation. Neither is it surprising if low status eventually extends to all of science and technology, leading to avoidance of these fields by most of our brainiest youngsters.

DECISIONS

Decision-making now requires deep understanding of technology and electronics, since these have entered into every other field of human activity. Thirty years ago,a company director unable to change a tyre on his car could still be expected to make the right decision on whether to spend a million on new record presses in the factory or not. Today, entering production of, for example, CD late in the day, in ignorance of the coming of DAT could be fatal. Likewise, being unable to foresee the potential of DAT technology for application as computer memory in comparison with other forms can also mean taking the wrong course. Once done, it will be very difficult to enter the winning stream, since most patents will in the meantime be in possession of the competitor company who took the right course at the time.

What hope has a company chairman when confronted with choices he cannot comprehend, let alone make any decision between often conflicting advice given by his experts? But being 'in charge' he at least has to pretend he knows where he is going, so he often follows the advice of the expert who happens to have the loudest voice, or the majority of board room members all as blind as himself.

Most engineers, especially those in electronics and allied fields, do not realize the great gulf that separated them from people in other professions, where mediocrity is the norm. While those in electronics deal daily with standards measured in nanoseconds, distances measured in the wavelengths of light, thicknesses of one atomic layer, and consider distortions of 0.001% or a failure rate of 1% of manufactured items as excessive, the rest of society is used to thinking that a quarter of an inch is the pinnacle of exactness; and those people who belong to the legal profession applying the law and its failure-rate of 65% – i.e. the number of re-offenders, after having been through the system once, supposedly to be cured of their bad habits – seem quite content to make a good living out of their job. If I were navigating my aircraft in such a way that 65% of the time I would arrive at the wrong airport, or would smash my undercarriage every second landing, I would retire from that job long before I would expect to be thrown out.

While writing this, I listened to Alistair Cooke reading his *Letter from America*, wherein he told of the golfer who recently, after bashing a ball into a hole in the ground, – admittedly from some distance – was given a prize of a quarter million dollars. Another golfer, also having bashed a ball into a hole in the ground was given a Rolls Royce worth over a hundred thousand dollars.

Now, I do not begrudge these people their money but, if I had to explain to a person from another world why bashing a ball into a hole in the ground was so highly valued by the people on this earth compared to the activities of those inventors of the body scanner who were given £5 for every expensive scanner sold, I would not be surprised if I would find myself faced with a difficult task.

What can be done to improve matters here in Britain? Compared with many other countries around the world, the people of Britain are not badly off or in desperate straits. There are many whose standard of living is high and whose complacency can be understood, if not condoned. There are also many success stories of firms able to compete with anyone in the world or even beating the best. Thus what ought to be said is that Britain is not doing badly, but could do vastly better.

Heinz Lipschutz is a retired airline captain, formerly flying Viscounts for British Airways.

SATELLITE SYSTEMS

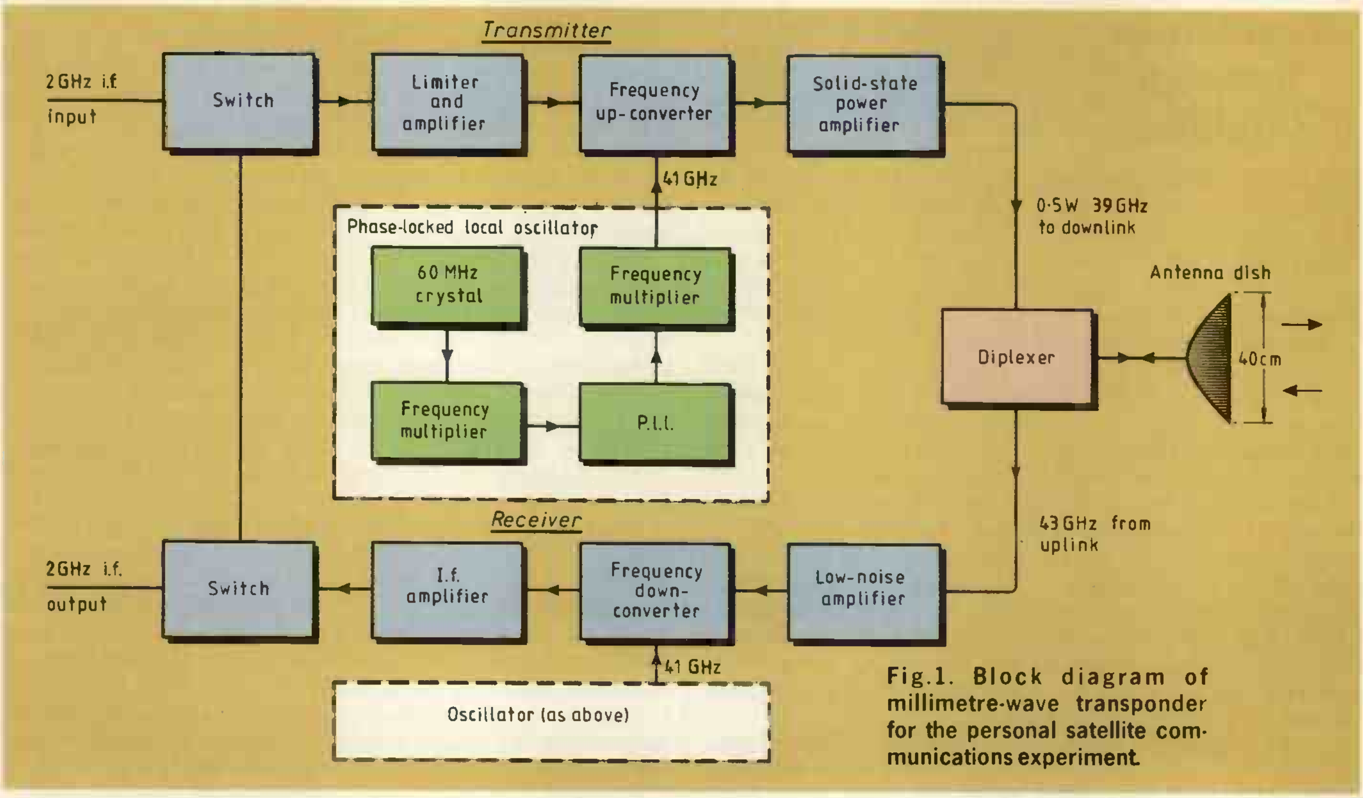


Fig.1. Block diagram of millimetre-wave transponder for the personal satellite communications experiment.

Personal mm-wave satcoms

When the Japanese ETS-VI geostationary test satellite is launched in 1992 it will be carrying a millimetre-wave transponder for experiments with a personal satellite communications service. The word personal here means that the earth terminals will be for exclusive use by individuals, or perhaps very small groups of people.

Millimetre waves, of course, allow antenna reflectors to be very small to achieve a given gain and directivity. So earth terminals can be made compact and light for carrying about either as portable or as transportable units. The main engineering problem is in obtaining adequate r.f. amplification at frequencies above 30GHz.

Five experimental systems are to be tried out. One is for slow-speed video news gathering, working at a data rate of 512kbit/s. Reporters will carry around a small, portable terminal with a 40cm diameter uplink dish. The second application will be the collection of geophysical or meteorological data from specific places. Portable terminals will be taken to temporary measurement sites only when needed there, to monitor earthquakes, volcanic eruptions or other natural phenomena.

Video telephony and conferencing will be a third experiment. Another will be centred on the Pacific Ocean region and will provide both personal communication services for the various islands and information exchanges between libraries and universities in major cities. The fifth system will be a mobile radio type service for travellers in land vehicles. It will provide communication, position finding and localized information about such things as traffic conditions, accidents and blocked roads.

Engineers from the Radio Research Laboratory of the Japanese Ministry of Posts and Telecommunications and from the NEC company gave a description of the proposed mm-wave scheme at the 38th Congress of the International Astronautical Federation at Brighton. Uplinks will operate in the 43.5–47GHz mobile-satellite frequency allocation and downlinks in the related 37.5–39.5GHz band.

At these frequencies the antenna diameters can be as small as 30cm for earth terminals and 40cm on the spacecraft to achieve substantial gains. Antenna gains of 37–38dB are expected for earth terminals and 39–40dB for the satellite transponder. The uplink transmitter will have an r.f. output power of 0.5W and, with the antenna gains mentioned, the resulting e.i.r.p. will be about 35dBW. The satellite transmitter will have the same r.f. power output, giving a downlink e.i.r.p. of about 37dBW.

Received power is expected to be −142dBW at the satellite and −143dBW at the earth terminals. Overall the carrier power to noise density ratio is reckoned to be about 54dBHz.

These figures apply to personal communications based on a data rate of 64kbit/s – a standard rate in the telecommunications field. For the slow-speed video news gathering experiment, however, the faster data rate of 512kbit/s requires higher transmitter powers – 2W for the uplink and 4W for the downlink. Here the antenna sizes and gains are larger, the gains being in the range 40–48dB. Consequently the e.i.r.ps are also greater: 44dBW for the uplink and 53dBW for the downlink.

A block diagram of the planned mm-wave transponder for the ETS-VI satellite is shown in Fig.1. Weighing 11kg and consuming 44W of power, it will operate on the single-channel-per-carrier (s.c.p.c.) principle. The i.f. is 2GHz and the receiver noise figure 6dB. The 41GHz local oscillator needs a temperature stability of 3×10^7 for satisfactory s.c.p.c. operation.

Semiconductor devices are to be used throughout this transponder, and, of course, at the present level of the technology the choice of suitable transistors to operate in the mm-wave region is very critical. At 39GHz, for example, the solid-state r.f. power amplifier in the transmitter is required to provide a gain of 27dB or more, to give an r.f. output of 0.5W. The Japanese engineers have decided on a power amplifier consisting of several fet amplifiers phase-combined in parallel. They expect to use devices more advanced than the now familiar GaAs fets to achieve the required performance.

In the receiver part of the transponder, the 43GHz low-noise amplifier front-end will also use a fet. The developers expect that by the end of the present decade new devices with noise figures of 5.2 to 5.7dB at this frequency will be available. In the local oscillator a GaAs fet is used in an 11GHz voltage controlled oscillator which is part of a phase-locked loop. The output of this circuit is frequency-quadrupled to give 41GHz, thus providing an i.f. of 2GHz in the receiver frequency converter when mixed with the 43GHz incoming signal.

Laser links between satellites

Laser optical systems are now being developed in several countries as an alternative to radio for communication links between satellites. They have several advantages. One, of course, is that they provide a wide frequency spectrum and at the same time save space in the microwave or mm-wave radio bands.

Another advantage is that high gain can be achieved with small reflectors at optical frequencies. This allows the transmitter and receiver to be small and lightweight with low power consumption. These optical links also provide a high degree of privacy in communication and are largely immune from electrical interference.

But laser links do have a problem, relative to radio systems, because of their extremely narrow beam widths. Beam divergence is measured in microradians and a typical figure is about 8μrad. This makes acquisition difficult – keeping the transmitter and receiver accurately pointed at each other when they may be up to 50 000km apart – and introduces a need for special automatic pointing, acquisition and tracking systems in the satellites.

Nevertheless the development of laser systems for this kind of communication is going ahead fast, to judge from a recent IEE colloquium in London ('Inter-satellite links and on-board optical techniques'). One important application giving an impetus to the work is the need to collect data from low-orbiting satellites which are engaged in scanning the Earth for various kinds of information – environmental, meteorological, military and so on.

Because of the low altitudes of these satellites their orbital periods are very short – typically 90 to 100 minutes. To collect transmitted data from them directly entails having a chain of earth stations all round the globe if continuous reception is to be maintained. This is complicated and expensive. A cheaper solution is to use a few geostationary data-relay satellites which look down on the low-orbiting spacecraft and can see them for long periods.

Current examples of such relay stations are NASA's Tracking and Data Relay Satellites (TDRS). Three of them, TDRS-A -B and -C, were deployed by the space shuttle in 1983, 1985 and 1985 respectively. These, however, and other projected data relay satellites, all use radio links to the low-orbiting (and other) spacecraft.

Other benefits of direct communication links between satellites include the avoidance of double hops (cutting out earth stations), a better use of the available frequency spectrum and a less complicated earth segment. Communication between satellites in the geostationary orbit is called inter-satellite while that between geostationary and low-orbiting spacecraft is distinguished by the name inter-orbit.

According to several contributors from STC at the IEE colloquium, the wavelengths envisaged for laser links range from 10.6μm down to 0.85μm. These are really fixed by the currently available laser sources. The longest wavelength, 10.6μm, is produced by a CO_2 gas laser, but this device is unlikely to be used in practice because of its large size and weight, poor reliability and need for gas replenishment. Semiconductor lasers will generate wavelengths of 1.5μm (using GaInAsP), 1.3μm (using GaInAsP) and 0.85μm (using GaAlAs). A solid-state device using Nd:YAG as the lasing medium and pumped by a semiconductor diode is very much favoured, and will produce a wavelength of 1.06μm.

Powers generated by the semiconductor lasers are generally in the range 20–50mW, and it seems that about 30mW would be enough to establish an inter-orbit link. As an example, three of the STC researchers described a newly-developed device called a double quantum well laser, which gives 30mW of continuous radiation at 0.85μm.

But many of the contributors spoke of the desirability of achieving higher powers, in hundreds of milliwatts. Here the Nd:YAG solid-state laser seems very promising. G. Hacker of the West German aerospace firm MBB mentioned that recent American work had achieved 600mW from this type of device and himself described an MBB laboratory set-up which he said was capable of generating "one watt or more." This comprised one Nd:YAG laser used as an oscillator, followed by another Nd:YAG laser operating as an amplifier.

However, the amount of power needed depends on the type of laser radiation and the method by which the data signal modulates it and is detected at the receiver. Two techniques are being investigated. In the first the laser generates multi-frequency, incoherent radiation and is modulated in intensity by pulses. Here the process at the receiving end is called direct detection. In the second technique the laser produces single-frequency, coherent radiation. This is modulated in a similar manner to the carrier of a radio transmitter and the process at the receiving end is called coherent detection.

In general the second method is more sensitive and efficient because the demodulator acts as a very narrow band filter, rejecting most of the background noise. The coherent method therefore requires less transmitter power than the direct method. As an example, A.R. Goodwin of STC mentioned that a 50 000km inter-satellite link carrying a data rate of 120Mbit/s had been calculated to need 20mW of laser output power for coherent detection but ten times as much, 200mW, for direct detection.

But obtaining a single-frequency carrier from a laser for the coherent transmission system is not so easy. In practice a spectral line with a certain width in Hz is generated. What linewidth in the frequency spectrum is tolerable in a system depends on the modulation/detection scheme chosen. G. Hacker gave some examples of three different kinds of carrier keying and detection. Assuming a data rate of 120Mbit/s, a.s.k./homodyne required a linewidth of 250kHz, f.s.k./heterodyne required a linewidth of 4MHz, while p.s.k./homodyne required a linewidth of 25kHz.

Another problem with the coherent system is that the local oscillator laser in the receiver has to be made tunable. Because a low-orbiting satellite travels at a greater angular velocity than a geostationary one, any electromagnetic-wave link between them is subject to the Doppler effect, which changes the frequency of the propagated carrier wave as seen by the receiver. This means that the receiver l.o. laser has to be tunable over about 15GHz (assuming a wavelength of 1.06μm) to cope with the Doppler shift.

Receiving devices for optical links are, of course, photodetectors, and have to be as sensitive as possible for good communication efficiency. A. Hadjifotion and N.E. Jolley of STC reviewed semiconductor devices now being studied for this task, for both direct and coherent detection systems. According to them, avalanche photodetectors in silicon for wavelengths up to 1μm and in the alloy GaInAsP for wavelengths up to 1.6μm offer the most promising performance – which means a group of parameters including high values of quantum efficiency (photoelectrons per photon), gain and gain × bandwidth product.

Silicon and the alloy both have a typical quantum efficiency of 80%, the first with a gain × bandwidth product of 150GHz and the second with 10GHz. The STC speakers compared receiver sensitivities that might be obtained with avalanche photodetectors used in the two methods of detection. They said that, at 1.55μm wavelength and a data rate of 140Mbit/s, the receiver sensitivity to be expected for direct detection would be −50dBm and for p.s.k./homodyne coherent detection would be −67.9dBm – a "massive advantage" of about 18dB for the coherent method.

Two Marconi speakers discussed the problems of pointing, acquisition and tracking in narrow-beam laser links. P.E.G. Cope outlined methods of acquisition based on charge-coupled sensing devices. P.C. Wyatt, discussing beam stabilization techniques, said that any system for pointing, acquisition and tracking had to be capable of tracking to an accuracy of 0.3μrad in the presence of disturbances from the spacecraft and accelerations in the line of sight.

Satellite Systems is written by Tom Ivall

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Current-conveyor sine-wave oscillators

Using a unified representation for single current-conveyor oscillators, new circuits of this class can be discovered systematically.

MUHAMMAD TAHER ABUELMA'ATTI and NOURIA ABDULLAH HUMOOD

Because of its distinct advantages over the operational amplifier, the current-conveyor has attracted the attention of many researchers in the field of active filters and oscillators[1]. Over the past few years, a number of schemes have been developed for realising single current-conveyor active–RC sinusoidal oscillators[2–7]. But papers available on this subject are concerned only with one new circuit in each paper. This is because these circuits were discovered by accident or with the help of intuition.

Our objective in this article is therefore to provide a unified treatment for single current-conveyor active-RC sinusoidal oscillator circuits. Apart from the obvious advantage of unifying the analysis of this class of oscillator, this treatment leads to the systematic discovery of numerous single current-conveyor active-RC sinusoidal oscillators. We shall consider here the performance of a few specimen circuits and shall provide a selected catalogue of potentially useful oscillators of this type.

Figure 1 shows the generalized representation of a single current-conveyor multiple feedback configuration. Assuming that the current-conveyor is ideal with $i_X=i_Z$, $i_Y=0$, $v_X=v_Y$, routine analysis yields the characteristic equation of this circuit configuration given by

$$Y_1Y_7[Y_2+Y_3+Y_6+Y_8-Y_4-Y_5]+Y_1Y_2[Y_3+Y_5+Y_6] +[Y_1(Y_3+Y_5)(Y_8-Y_4)]+Y_2Y_8[Y_5+Y_7]-Y_1Y_4Y_6 +Y_2Y_3[2Y_5+Y_7+Y_8]+Y_6Y_8[Y_1+Y_2+Y_3+Y_7] +Y_3Y_6[Y_2-Y_4+Y_7]=0 \qquad (1)$$

This equation is complex and not easy to visualize. Therefore, the analysis in the following sections will proceed by considering some special cases.

CASE I

For $Y_6=Y_8=0$, equation 1 reduces to

$$Y_1Y_2(Y_3+Y_5+Y_7)+Y_3Y_7(Y_1+Y_2)+2Y_2Y_3Y_5= Y_1Y_5Y_7+Y_1Y_4(Y_3+Y_5+Y_7)$$

The oscillator circuits shown in Fig.2 resulted from performing all possible permutations to explore the possibility of oscillation. Table 1 summarizes the frequency of oscillation and the condition of oscillation for each circuit.

Fig.1. Single current-conveyor multiple feedback configuration.

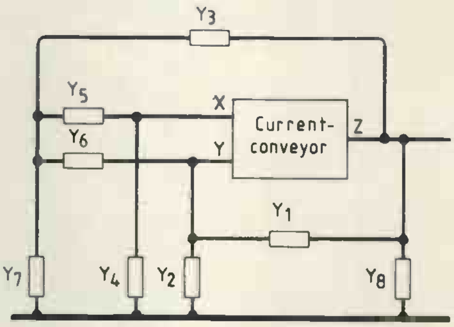
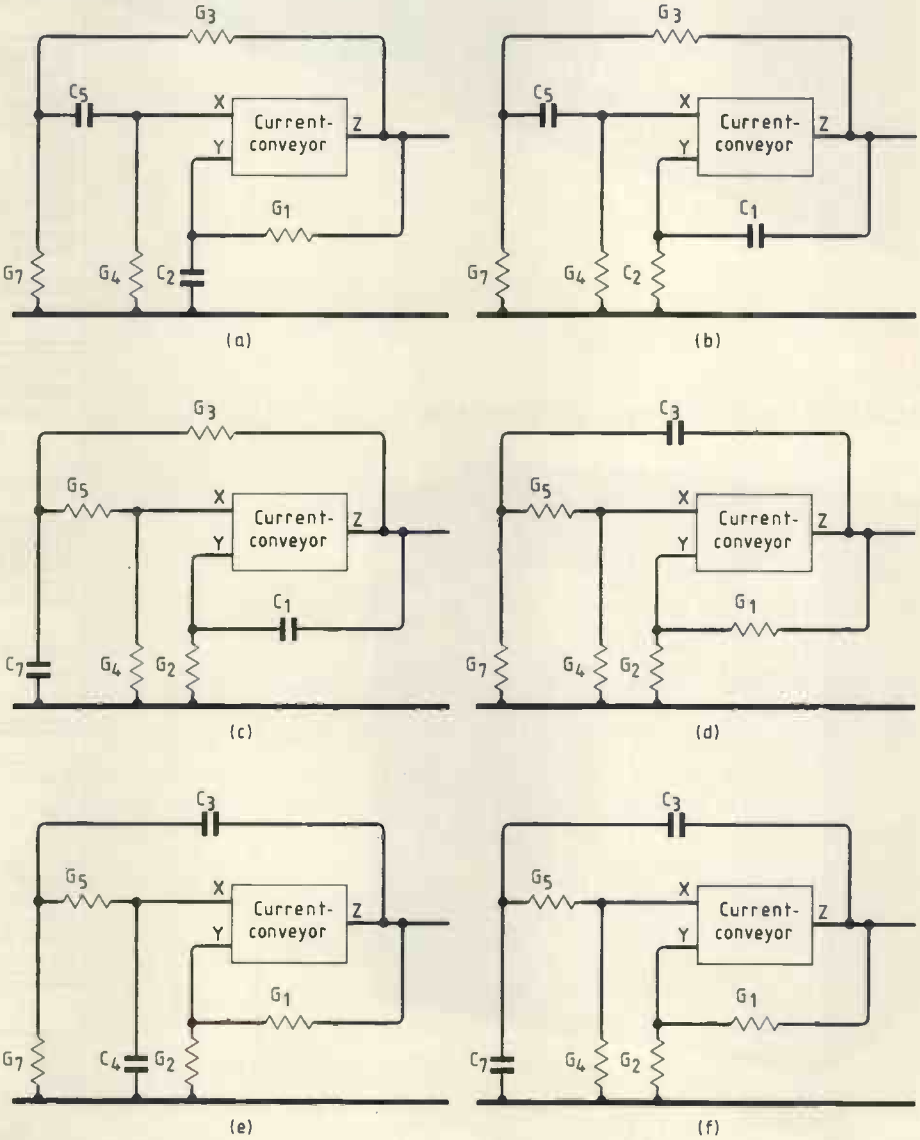


Fig.2. (below): these oscillator circuits are derived from Fig.1 with $Y_6=Y_8=0$.



CASE II

For $Y_1=Y_5=0$, equation 1 reduces to

$$Y_8Y_6(Y_3+Y_7+Y_2)+Y_3Y_7(Y_6+Y_2)+Y_8Y_2(Y_3+Y_7)=Y_3Y_6(Y_4-Y_2)$$

This yields the oscillator circuits shown in Fig.3. Table 2 summarizes the frequency and condition of oscillation for each circuit.

CASE III

With $Y_3=Y_5=0$ and $Y_6=\infty$, equation 1 reduces to

$$Y_4Y_1=Y_8(Y_1+Y_2+Y_7)+Y_1(Y_2+Y_7)$$

which yields the oscillator circuit shown in Fig.4. The frequency and the condition of oscillation of the circuit are given by

$$\omega_0{}^2=\frac{G_7G_8}{C_1C_2}$$

and $\quad G_8(C_1+C_2)=C_1(G_4-G_7)$.

CASE IV

With $Y_3=Y_8=0$ and $Y_1=\infty$, equation 1 reduces to

$$(Y_2-Y_4)(Y_7+Y_6+Y_5)+Y_7(Y_6-Y_5)=0$$

The process of permutation gives us the oscillator circuits of Fig.5. Table 3 summarizes the frequency and condition of oscillation for each circuit.

CASE V

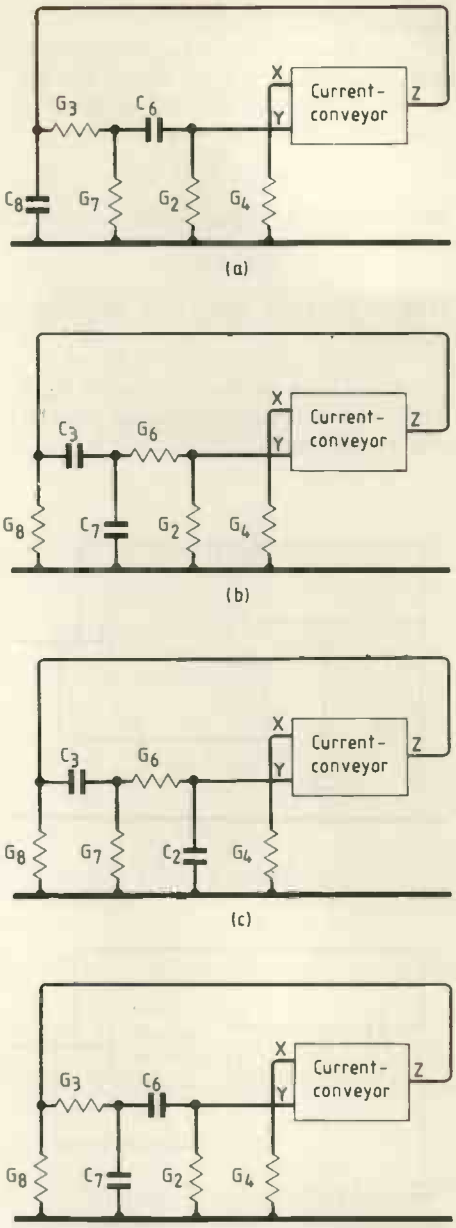
With $Y_4=Y_6=0$ and $Y_5=\infty$, equation 1 re-

Table 1. Frequency and condition of oscillation for the six oscillator circuits of Fig. 2.

Circuit	Frequency ($\omega_0{}^2$)	Condition of oscillation
a	$\frac{G_1[G_3G_4+G_4G_7-G_3G_7]}{C_2C_5[G_1+2G_3]}$	$C_2[G_1(G_3+G_7)+G_3G_7]=G_1C_5(G_4+G_7)$
b	$\frac{G_2G_3G_7}{C_1C_5[G_2-G_7-G_4]}$	$C_1[G_2G_3+G_2G_7+G_3G_7]+2C_5G_2G_3=C_1G_4(G_3+G_7)$
c	$\frac{2G_2G_3G_5}{C_1C_7[G_2+G_3-G_5-G_4]}$	$C_1C_2[G_3+G_5]+C_7G_2G_3=C_1G_4(G_3+G_5)$
d	$\frac{G_1G_7(G_2-G_4)}{2C_3C_5G_2}$	$(C_3+C_5)G_1G_2+C_3G_7(G_1+G_2)=(C_3+C_5)G_1G_4+C_5G_1G_7$
e	$\frac{G_5G_7-G_2(G_5+G_7)}{C_3C_4}$	$C_3[(G_1+G_2)G_7+G_1G_2+2G_3G_5]=C_4G_1(G_5+G_7)$
f	$\frac{G_1G_5(G_2-G_4)}{C_3C_7(G_1+G_2)}$	$(C_3+C_7)G_1[G_4-G_2]+C_7G_1G_5=2C_3G_2G_5$

Table 2. Frequency and condition of oscillation for the circuits of Fig. 3.

Circuit	Frequency	Condition of oscillation
a	$\frac{G_3G_7G_2}{C_6C_8(G_2+G_3+G_7)}$	$G_3C_6(G_7+G_2)+G_2C_8(G_3+G_7)=G_3G_4C_6$
b	$\frac{G_2G_6G_8}{C_3C_7(G_6+G_2)}$	$G_6G_8(C_3+C_7)+G_2G_8(C_3+C_7)+C_3G_2G_6=C_3G_4G_6$
c	$\frac{G_6G_7G_8}{C_3C_2(G_6+G_7+G_8)}$	$G_6G_8(C_2+C_3)+G_6G_7C_3+G_7G_8C_2=C_3G_4G_6$
d	$\frac{G_2G_3G_8}{C_6C_7(G_3+G_8)}$	$G_8C_6(G_3+G_2)+G_2G_3C_7+G_3G_8C_7+G_2G_3C_6=G_4G_3C_6$



(a) (b) (c) (d)

Fig.3. (above) Oscillators derived from Fig.1 with $Y_1=Y_5=0$.

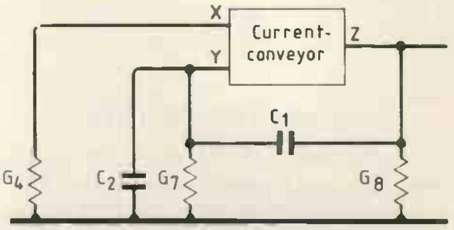
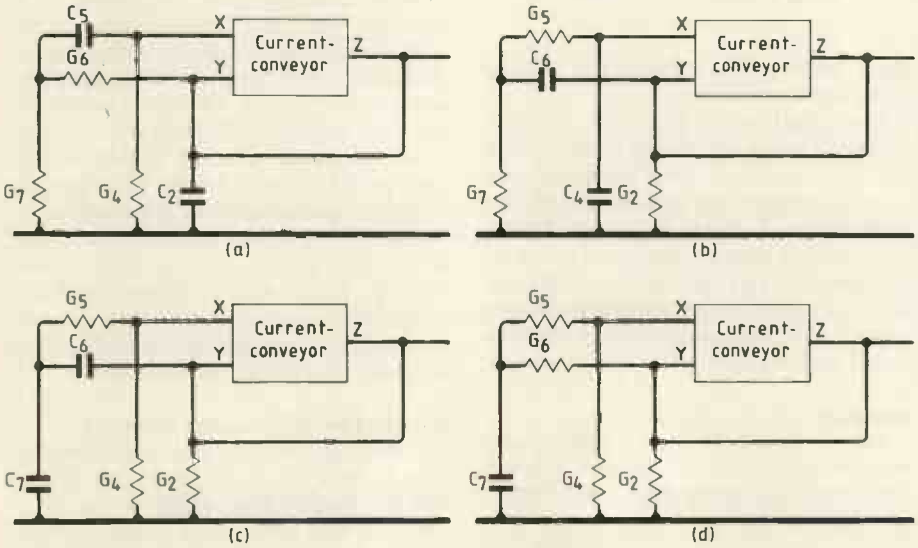


Fig.4. Oscillators derived from Fig.1 with $Y_3=Y_5=0$, $Y_6=\infty$.



(a) (b) (c) (d)

Fig.5. Oscillators derived from Fig.1 with $Y_3=Y_8=0$, $Y_1=\infty$.

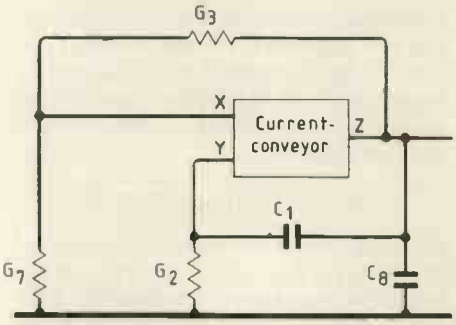


Fig.6. Oscillator derived from Fig.1 with $Y_4=Y_6=0$, $Y_5=\infty$.

duces to

$$Y_1Y_7=Y_1(Y_2+Y_8)+Y_2(2Y_3+Y_8)$$

and the oscillator circuit shown in Fig.6 results. Frequency and the condition of oscillation of the circuit are given by

$$\omega_0{}^2=\frac{2G_2G_3}{C_1C_8}$$

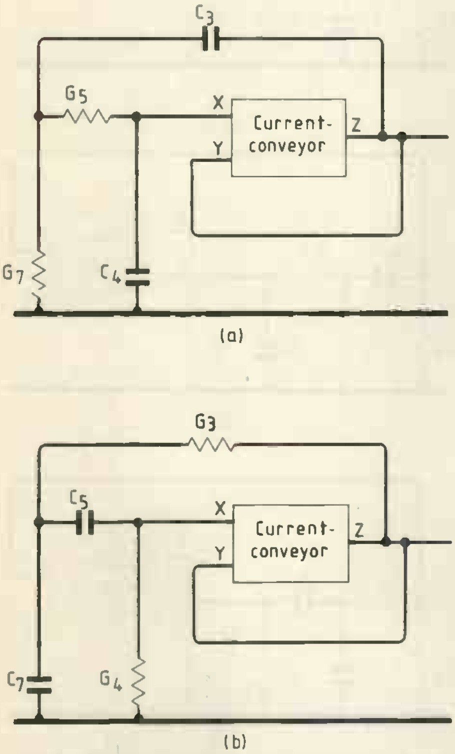
and $$C_1G_7=C_1G_2+C_8G_2.$$

CASE VI

With $Y_2=Y_6=Y_8=0$ and $Y_1=\infty$ equation 1 reduces to

$$Y_3(Y_4-Y_7)+Y_4(Y_5+Y_7)+Y_5Y_7=0$$

which results in the circuits shown in Fig.7. Table 4 summarizes the frequency and condition of oscillation for each circuit.



(a)

(b)

Fig.7. Oscillator circuits derived from Fig.1 with $Y_2=Y_6=Y_8=0, Y_1=\infty$.

FURTHER POSSIBILITIES

Obviously, several other special cases can be considered and numerous oscillator circuits can be obtained by performing all the possible permutations. Also, it is worth pointing out that permutations in the six cases considered here employ a single passive element per branch; either a resistor or a capacitor, and two capacitors only per circuit. However, by allowing more than one element per branch and/or more than two capacitors per circuit, hundreds of new oscillator circuits could be obtained.

EXPERIMENTAL RESULTS

Although the current conveyor realisation[8] shown in Fig.8 is imperfect[1], highly stable oscillations have been obtained with it. Table 5 summarizes the performance of a few selected sample circuits. With a high-performance current-conveyor implementation[9], better results over a wider frequency range would be obtained.

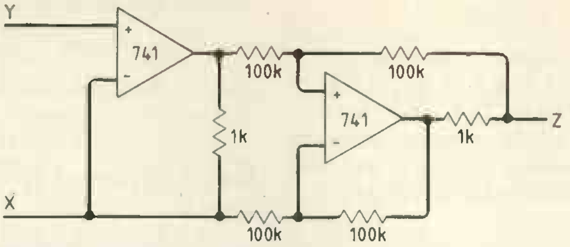


Fig.8. Circuits illustrated here are based on this twin op-amp current conveyor arrangement. Special-purpose current-conveyor i.cs could bring improved bandwidth and output drive capability.

Table 3. Frequency and condition of oscillation for the oscillator circuits of Fig. 5.

Circuit	Frequency	Condition of oscillation
a	$\frac{G_6G_7-G_4(G_6+G_7)}{C_2C_5}$	$C_2(G_6+G_7)=C_5(G_4+G_7)$
b	$\frac{G_5G_7-G_2(G_5+G_7)}{C_4C_6}$	$C_6(G_2+G_7)=C_4(G_5+G_7)$
c	$\frac{G_5(G_2-G_4)}{C_6C_7}$	$(C_6+C_7)(G_2-G_4)=C_7G_5$
d	$\frac{G_6(G_2-G_4)}{C_5C_7}$	$(C_5+C_7)(G_2-G_4)=C_7G_6$

Table 4. Frequency and condition of oscillation for the circuits of Fig. 7.

Circuit	Frequency	Condition of oscillation
a	$\frac{G_5G_7}{C_3C_4}$	$C_3G_7=C_4(G_5+G_7)$
b	$\frac{G_3G_4}{C_5C_7}$	$C_7G_3=G_4(C_5+C_7)$

Table 5. Summary of the performance of five new selected sample circuits.

Circuit	Component values	Frequency range
Fig.2a	$R_1=5.6k$, $R_3=1k$, $R_4=10k$, $R_7=2.5k$, $C_2=1n$, $C_5=19n\rightarrow1\mu$	5.3kHz→305Hz
Fig.3a	$R_2=7\cdot4k$, $R_3=2.5k$, $R_4=1k$ $R_7=10k$, $C_6=10n$ $C_8=1n\rightarrow30n$	2·5kHz→1.11kHz
Fig.4	$R_4=2.5k$, $R_7=5k$, $R_8=10k$ $C_2=1n$, $C_1=1n\rightarrow20n$	11.9kHz→1.75kHz
Fig.5a	$R_4=2.5k$,$R_6=1k$, $R_7=1k$ $C_2=1n$, $C_5=3n\rightarrow300n$	28.9kHz→0.6kHz
Fig.6	$R_2=2.5k$, $R_3=1k$, $R_7=1k$ $C_8=3n$, $C_1=5n\rightarrow1\mu$	30.8kHz→1.7kHz

The practice of realising current-conveyors using operational amplifiers and resistors results in poor bandwidth and output capability into even moderately low loads. However, research may result in the production of high-performance i.c. current conveyors. In this case the i.c. technology used will play an important role in deciding which of the numerous circuits derivable from Fig.1 are preferable.

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EF89	2.50
EF91	2.95
EF92	6.37
EF93	1.50
EF94	2.50
EF95	5.99
EF98	2.00
EF183	2.00
EF184	2.00
EF804S	12.00
EF805S	15.00
EH90	1.75
EK90	1.50
EL32	2.50
E133	4.00
EL34MUI	5.00
EL36	2.50
EL41	2.80
EL42	2.50
EL81	5.25
EL83	6.00
EL84	2.25
EL86	2.75
EL90	3.25
EL91	7.39
EL95	2.00
EL156	30.00
EL360	18.50
EL500	3.00
EL509	10.00
EL821	13.00
EL822	13.97
ELL80	25.00
EM34	8.00
EM80	2.50
EM81	2.50
EM84	2.00
EM85	2.75
EM87	2.50
EN32	25.00
EN91	6.50
EN92	6.96
EY51	2.75
EY81	2.50
EY83	2.50
EY84	9.24
EY86	1.75
EY88	1.75
EY500A	3.00
EY802	1.75
EZ35	1.75
EZ40	2.50
EZ41	2.50
EZ80	1.50
EZ81	1.50
EZ90	3.00
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GXU4	44.50
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GY501	3.00
GZ32	4.00
GZ33	4.75
GZ34	4.00
GZ37	4.75
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KT66	15.00
KT77 Gold Lion	12.00
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KTW61	2.50
KTW62	2.50
KTW63	2.50
M8079	12.34
M8080	8.25
M8081	9.82
M8082	9.69
M8083	10.25
M8091	10.43
M8096	6.80
M8097	8.10
M8098	8.15
M8099	8.00
M8100	10.30
M8136	11.75
M8137	12.25
M8140	6.00
M8141	6.50
M8142	8.75
M8144	7.50
M8149	6.50
M8161	9.35
M8162	11.75
M8163	8.25
M8190	5.00
M8195	10.85
M8196	7.50
M8204	7.05
M8212	11.37
M8223	6.00
M8224	6.30
M8225	4.50
M8248	14.03
MD2901	115.00
MU14	2.50
MX119	55.00
MX123	86.00
MX145	61.50
MX151	18.30
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MX166	164.00
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OA3	2.50
OA4	6.00
OB3	2.50
OC2	4.35
OC3	2.50
OD3	2.50
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PC86	2.50
PC88	2.50
PC95	1.75
PC97	1.75
PC900	1.75
PCC84	1.50
PCC85	1.50
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PCC189	2.50
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PCE82	2.00
PCF80	2.00
PCF82	1.50
PCF86	2.50
PCF87	2.00
PCF200	3.25
PCF201	3.25
PCF801	2.50
PCF802	2.50
PCF805	1.70
PCF806	1.70
PCF808	1.70
PCL82	2.00
PCL83	3.00
PCL84	2.00
PCL85	2.50
PCL86	2.50
PCL805/85	2.50
PD500	6.00
PE06-40N	45.00
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PL36	2.50
PL81	1.75
PL81A	2.00
PL82	1.50
PL83	2.50
PL84	2.00
PL504 5	2.50
PL508	5.50
PL509	6.00
PL519	6.00
PL801	1.50
PL802	6.00
PY33	2.50
PY81	1.50
PY82	1.50
PY83	1.25
PY88	2.00
PY500A	4.00
PY800	1.50
PY801	1.50
QF451	82.50
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S130	6.00
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5Z4G	2.50
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6-30L2	1.75
6AB4	1.75
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6AF4A	4.25
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6AH6	5.00
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6AT6	1.25
6AU5GT	5.00
6AU6	2.50
6AV5GA	4 50
6AV6	1.50
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6B8	3.25
6BA6	1.50
6BA7	5.00
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6BC4	4.00
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6BH6	2.50
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6BK4	4.50
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6CB6A	2.50
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6F23	1.60
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6F33	33.50
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6H3N	2.75
6H6	3.00
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6J6	8.93
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6L6GC (GE)	5.75
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6N7	3.00
6P25	4.00
6Q7	3.75
6R7	3.25
6RHH8 6KN8	10.00
6SA7	3.00
6SC7	2.75
6SF7	2.50
6SH7	3.00
6SJ7	3.25
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6SL7GT	3.00
6SN7GT	3.00
6SQ7	3.40
6SR7	4.00
6SS7	2.75
6U5G	3.50
6U8A	2.25
6V6GT	4.25
6X4	3.00
6X5GT	1.75
7B7	2.50
7C5	4.00
7C6	2.50
7H7	4.00
7R7	4.25
7S7	3.50
7Y4	2.25
7Z4	2.00
12AH8	5.00
12AT6	1.50
12AT7	1.75
12AU6	2.50
12AU7	1.75
12AV6	2.50
12AV7	3.50
12AX7	1.75
12AY7A	4.00
12B4A	3.50
12BA6	2.50
12BE6	2.50
12BH7	2.75
12BY7	3.00
12E11TT	28.00
12E14	65.00
12E1	20.00
13E1	170.00
19H5	47.50
24B9	67.25
30C15	2.00
30C17	2.00
30C18	2.00
30F5	1.60
30FL1/2	1.38
30FL12	1.80
30FL14	2.00
30L1	1.50
30L15	2.00
30L17	2.00
30P4	2.50
30P19	2.50
30PL1	3.00
30PL14	1.80
30PL15	1.80
35W4	1.00
50C5	1.50
75B1	6.05
75C1	4.50
85A1	7.50
85A2	6.45
90AG	20.00
90AV	20.00
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90CG	14.54
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6005	2.25
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6057	12.25
6058	12.34
6059	6.00
6061	6.00
6063	3.75
6064	10.25
6067	11.75
6072	6.00
6080	14.00
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6550	10.00
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7400	0.35
7401	0.36
7402	0.36
7403	0.36
7404	0.42
7405	0.42
7406	0.48
7407	0.55
7408	0.36
7409	0.36
7410	0.36
7411	0.40
7312	0.42
7413	0.36
7416	0.48
7417	0.48
7420	0.48
7422	0.36
7423	0.36
7424	0.36
7427	0.36
7428	0.36
7430	0.36
7432	0.36
7433	0.55
7437	0.36
7438	0.36
7439	0.36
7440	0.36
7441	0.48
7442	1.25
7450	0.30
7451	0.30
7453	0.30
7454	0.30
7460	0.30
7470	0.48
7472	0.30
7473	0.48
7474	0.36
7475	0.65
7476	0.48
7480	0.32
7483	0.48
7484	0.72
7486	0.54
7490	0.72
7491	0.36
7492	0.54
7493	0.54
7494	0.78
7495	0.65
7496	0.60
7497	3.90
74100	0.84
74107	0.36
74109	0.54
74110	0.48
74111	0.51
74116	1.50
74118	1.20
74119	1.50
74120	0.75
74121	0.54
74122	0.70
74123	0.60
74125	0.60
74126	0.54
74128	0.55
74136	0.70
74141	0.46
74143	1.30
74145	0.72
74147	1.50
74148	1.40
74150	1 60
74151	0.36
74154	1.40
74155	0.60
74156	0.48
74159	1.75
74170	1.20
74172	4.00
74173	0.72
74174	0.60
74175	1.00
74176	1.00
74180	1.48
74190	1.20
74191	1.20
74192	1.10
74193	0.60
74194	1.10
74195	0.72
74196	1.00
74197	1.00
74198	2.20
74199	2.20
TAA570	1.75
TAA630S	1.75
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Continued from page 263

Variations on the theme of patents

far better to spread the novelty widely and get it used wherever it is beneficial. Yet just declaring it "in the public domain" is not ideal, because the inventor has to live with the results of his brain child, so he needs some vestige of control over what results, both from a commercial and an ethical point of view, since anything new has potential for good or evil.

However, to leave such a decision to the inventor would lead to legal wrangles just as bad as infringement ones.

GLIMMER OF HOPE

Although the future looks bleak, there are one or two rays of hope that are worth exploring. If one has a very broad or widely applicable idea, then it is in no one company's interest to adopt it because the others could gang up and oppose it. We therefore tend to have stale mate. If, however, one can somehow manage to introduce it to everyone on equal terms, then there is no reason why it should not be readily adopted. Ray Dolby seems to have managed this with his Dolby noise limiting system, which is now widely used on tape and other sound reproduction systems.

This has been hailed as a miracle in licensing and the key appears to be the electronic chip. Once a chip has been successfully made for a duty, it is idle to build the circuit from components. Further, the product companies paying the royalty have a strong interest in working together for the common good. The result is self policing and co-operative action to enhance and further exploit the technology.

Whether this is applicable to other than a chip remains to be seen but most inventions will have a key item, the production costs of which will decrease with the usage, so the merits are perhaps worth exploring.

In retrospect, there are earlier illustrations of the same theme; the 555 timer chip has replaced the cam-motor-microswitch clocks of the 60's.

My attempt at using electronics instead of pneumatics in the 1950's led to worries about the explosion hazard in chemical plants and oil refineries. The normal foil to this, explosion proof housings, was most ungainly but the alternative – intrinsic safety – was difficult to apply. The answer was to use the Zener safety barrier but there were legal and commercial difficulties.

Eventually at the suggestion of an Inspector of Factories, a unit was designed by a committee representing a number of manufacturers, and certified for general use at a solution to this safety problem. It has since become the world standard way of dealing with the bulk of such problems. There were no patent rights outside the UK, but the idea spread and money was made out of books, seminars and consultancy work, which is probably more satisfying than royalties anyway.

I conclude that patents are fine to 'make-em-listen' but it takes hardware to promote action.

Bob Redding is director of Design Automation Ltd, in Maidenhead.

APPLICATIONS SUMMARY

Linear array design manual

Originally, semi-custom linear devices were almost as difficult to design as full-custom i.cs since they required interconnection of resistors and transistors scattered about the chip in a semi-random fashion.

Modern fixed arrays consist of uncommitted component modules arranged in a grid so design involves determining the function of each block on the grid. From the ground up, grid-based arrays would also be difficult to design, but this approach allows the functions of the blocks to be standardized. Turning a block into say an op-amp is simply a matter of selecting the required function from a macrocell library.

Design is further simplified since performances of the various functions in the macrocell library relate to industry standard devices. Raytheon's RLA series linear-array design manual says that most engineers will find designing with RLA series devices about as difficult as designing a discrete-component circuit and two-sided printed-circuit board.

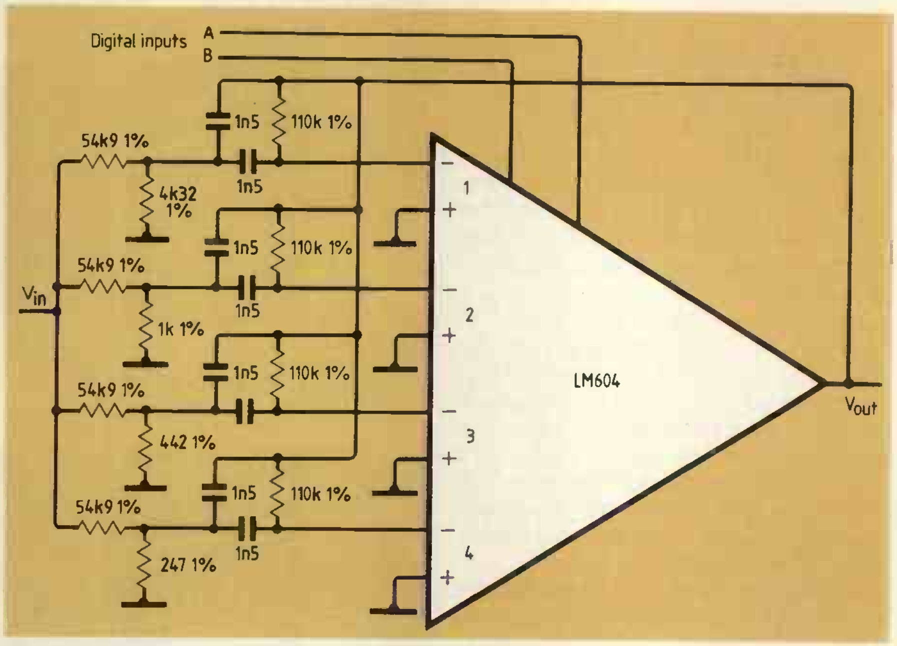
The design manual is a comprehensive guide that discusses array structure, i.c. design, component specifications and marcocell data. It includes a full discussion of how the programmable differential amplifier shown here is obtained from basic specifications and of how the final circuit is evaluated. In the model library description, subcircuit listings for the Spice emulator are given.

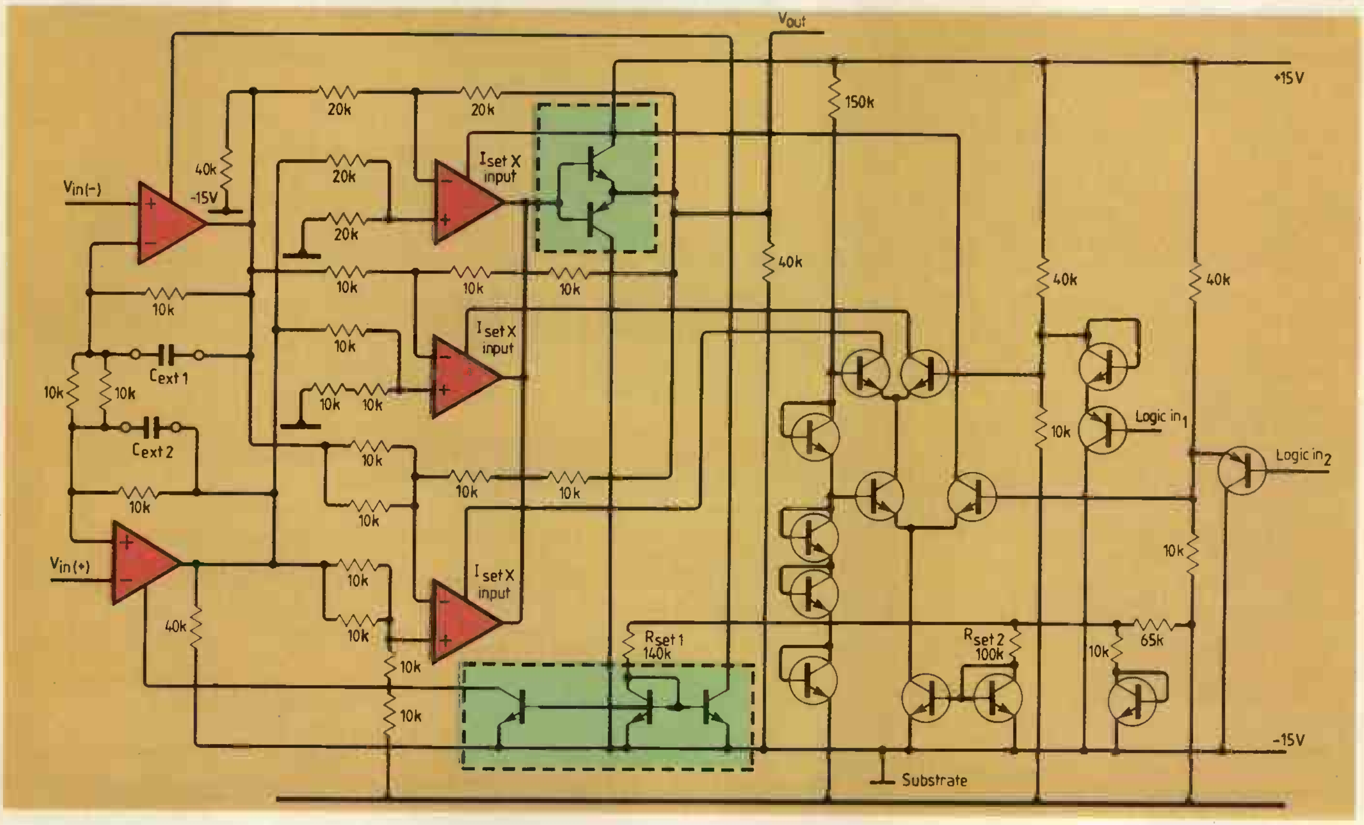
Programmable bandpass filter

An LM604 four-channel multiplexing amplifier provides a simple bandpass filter whose centre frequency can be selected under microprocessor control. Each channel has a 2kHz bandwidth and a gain of one at its centre frequency.

To simplify microprocessor interfacing, the device has chip-select, enable and write inputs to latch the channel address. Using enable and write inputs, it is possible to switch the amplifier output to high impedance so that outputs from a number of devices may be connected together, although that may not be appropriate for this particular example.

There are no further details of this example in the LM604 data sheet from National Semiconductor, but full specifications of the i.c. are given, and an example of how to connect outputs of two devices together.





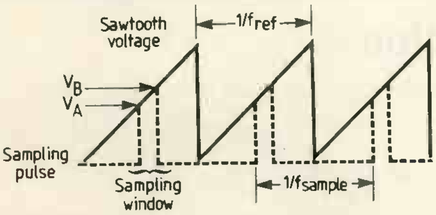
APPLICATIONS SUMMARY

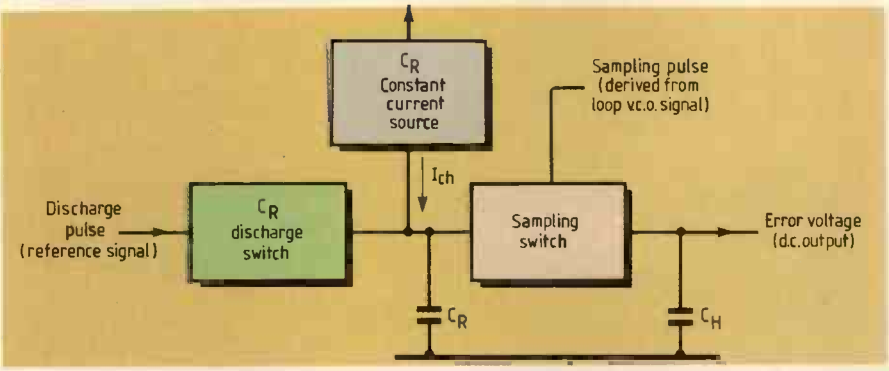
Frequency synthesizer with analogue phase detector

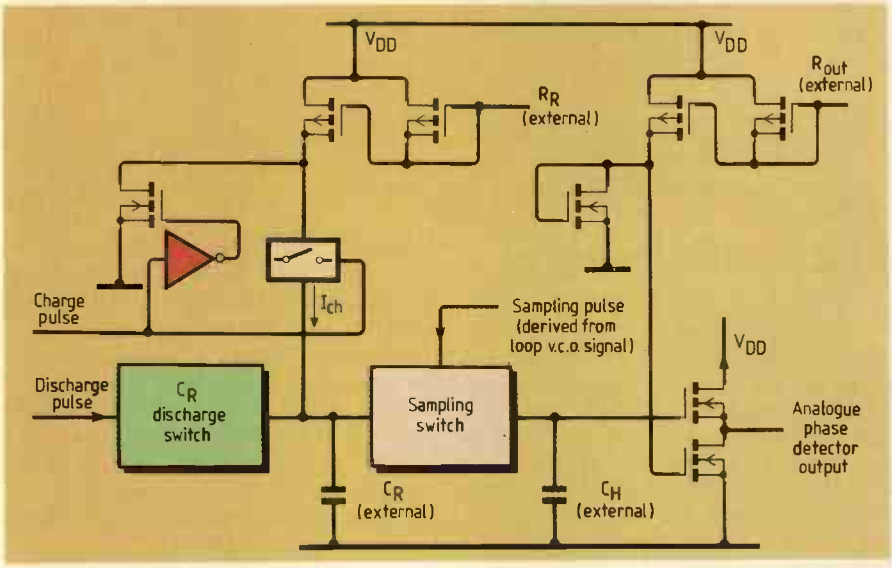
In frequency synthesizer designs, digital phase detectors normally need heavy filtering, which compromises overall loop performance. The higher-gain analogue phase detector in the MC145159 synthesizer reduces v.c.o. modulation sidebands and allows greater loop bandwidths.

This analogue detector is actually a sample-and-hold circuit with a new feature that makes its output much cleaner than would be possible with traditional sample-and-hold detector configurations. Normally during the sample window, the ramp signal feeding the hold capacitor is still rising, causing ripple on the output, as shown below. After sampling, the ramp continues to rise, causing problems with parasitic ramp feed through. Ramp clamping, as the new feature is called, stops the ramp before it is sampled, producing a clean output almost ready to drive the synthesizer v.c.o.

In note AN969 covering operation of the MC145159, Motorola says that the device is suitable for applications including two-way radios, cellular radio telephones and avionics equipment. It has three programmable counters, one for the reference frequency and two for division, that can be loaded through the serial interface of a c-mos microcomputer.







Addresses

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Crownhill
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0908 568989

Sun Microsystems Europe
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31 Pembroke Broadway
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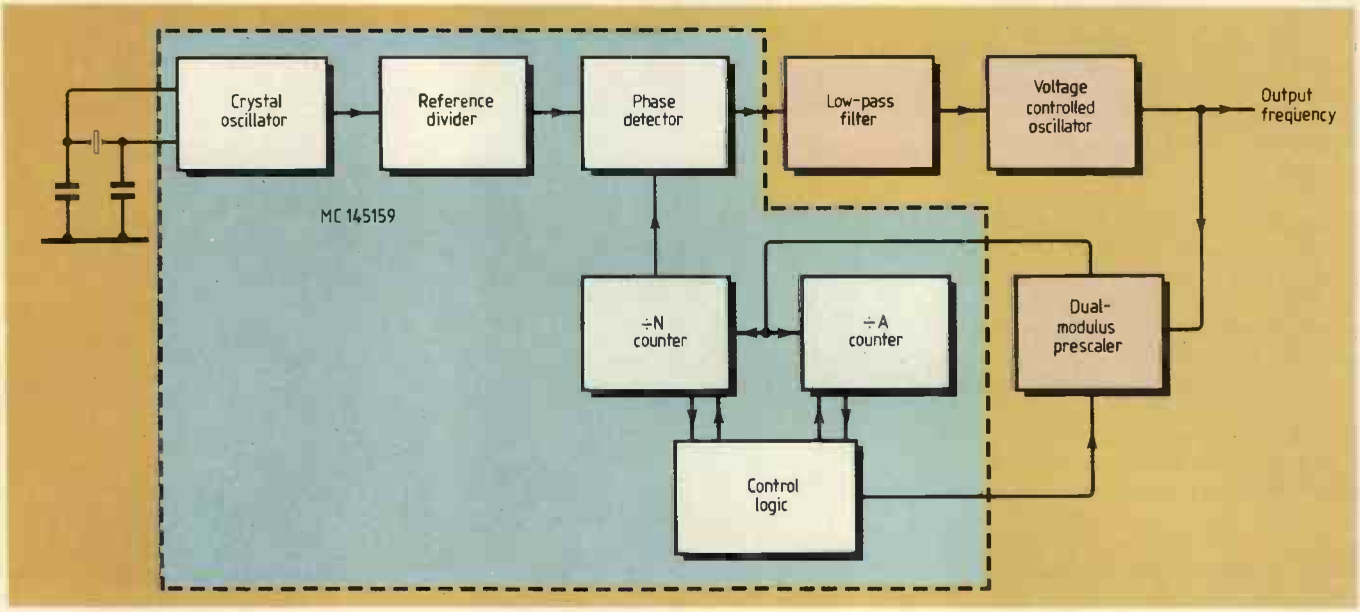
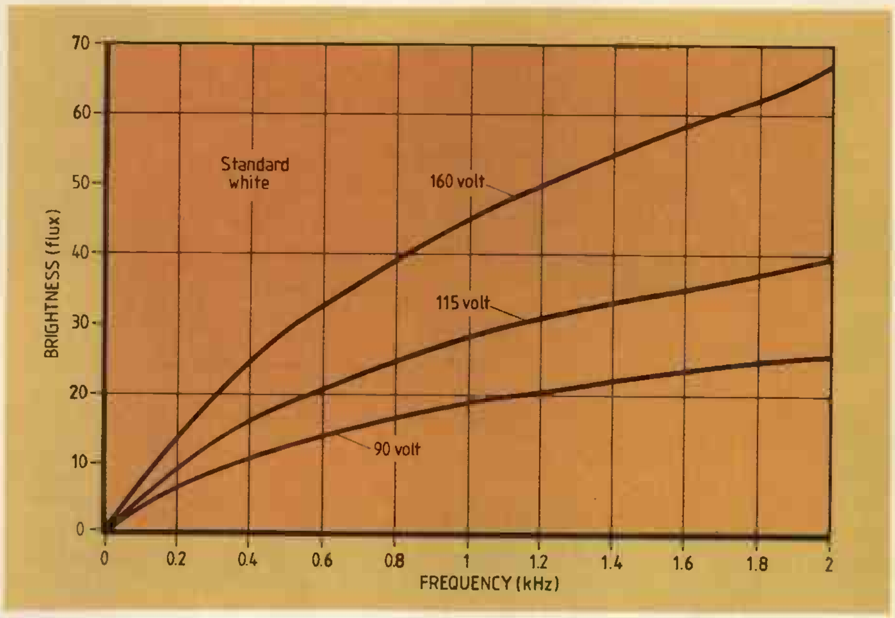


APPLICATIONS SUMMARY

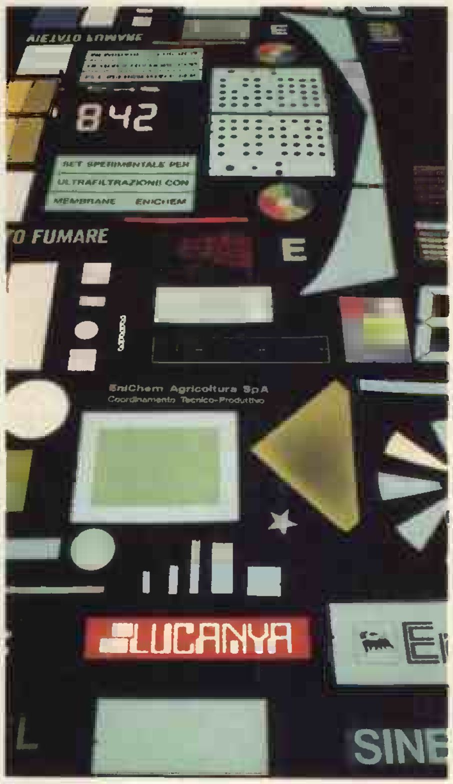


Electroluminescent panels

When first introduced, electroluminescent panels were only available in green and were prone to "hot spots". Modern panels still require a relatively high voltage a.c. supply but they are more efficient and can be made in a range of colours. Adding dyes to the phosphors or overlaying photoluminescent material allows colours such as white and red to be produced.

Improved manufacturing techniques result in a constant and uniform light output over the entire panel surface without the need for heating, and greater efficiency. Sacrificing brightness, it is possible to run the higher efficiency green panels from a 60Hz supply of about 100V. Less efficient panels of other colours still need about 100V at 400Hz but specially designed d.c.-to-a.c. converters of about 25mm^3 are available.

Theory behind these panels and technical details relating to light output and spectral performance are contained in a booklet called Introduction to electroluminescence produced by Enichem and available through Steatite. Included in the booklet are a discussion of radiometric versus photometric units and graphs showing brightness against frequency for the various display colours.

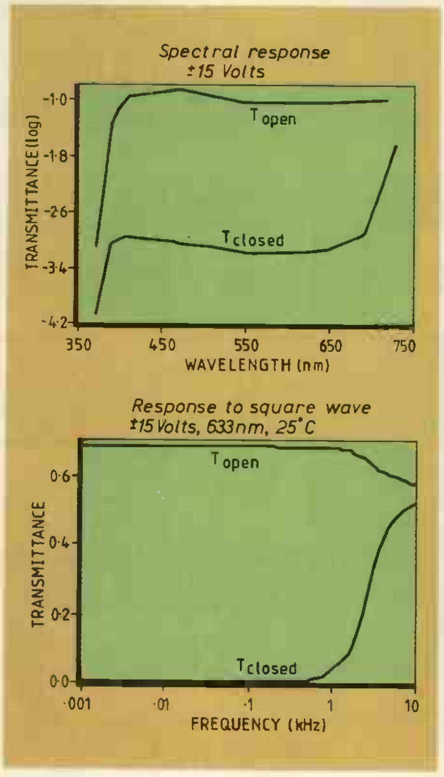


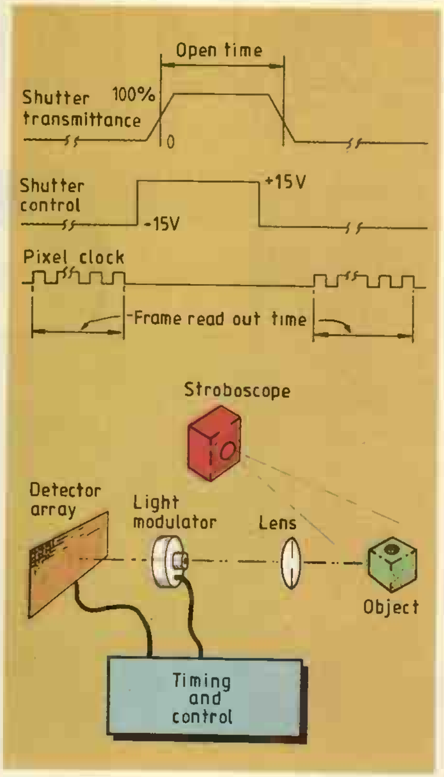
Liquid crystal light modulator in image recognition

Ferroelectric liquid-crystal shutters that switch in a few hundred microseconds are now readily available for evaluation in industrial and commercial applications. Such light modulators have been used successfully in three-dimensional television and light beam switching experiments but there must be many less obvious applications yet to be discovered. One such application is suggested by Displaytech in a very short note that describes using the company's 150µs light modulator to enhance computer image recognition.

In machine vision, moving objects appear blurred so image freezing is introduced to obtain a sharp picture. Normally a stroboscope is used for image freezing but unless the object is in complete darkness, unwanted light reaches the camera or detector while the stroboscope is off. Adding a light modulator provides a very fast shutter that only opens when the stroboscope is activated, hence blocking unwanted light.

The one-sheet note is part of a booklet containing data on the modulator and discussing its operating principles. A further equally short note describes using pulse-width modulation for light attenuation. Optilas distributes the modulator in the UK.





TELECOMMS TOPICS

Euro-cellular

Alcatel, Nokia and AEG have signed an agreement covering development, manufacturing, marketing and sales of pan-European digital cellular systems operating to the GSM standard. This agreement, which will remain in effect until 1993, supersedes a memorandum of understanding signed last October at Telecom 87.

The consortium will be known as ECR900, i.e. European Cellular Radio 900MHz, and will have its 'programme office' in Stuttgart, West Germany at the Standard Elektrik Lorenz subsidiary of Alcatel. Specific tasks will be allocated among the three companies and it expects to employ up to 400 engineers. They will share the total costs, expected to involve some 150 million ECU, or roughly £100M, over the next four years.

Fifteen of the 26 CEPT countries have already agreed to the introduction of the GSM system.

Mercury/ Netherlands co-operation

Mercury Communications Ltd and the Netherlands PTT have signed agreements covering the provision of switched telephone services and the planning for an optical fibre link between the UK and the Netherlands.

The first agreement covers the provision of all public switched and private leased services between the two countries with service being planned to begin early this year. The other agreement, for the joint planning of an optical fibre submarine cable system linking the UK and the Netherlands, covers a multiple-fibre unrepeatered digital link of some 170km in length. It is expected to come into operation in 1989.

Stock Exchange's System X

The London Stock Exchange has switched over to a private System X digital telephone network supplied, installed and commissioned by Plessey. This provides the most modern communications facility of its kind in the world.

The new exchange privately links the regional stock exchanges at Glasgow, Liverpool, Manchester, Birmingham and Dublin with the main London Stock Exchange. Remote concentrator units, which form an integral part of the System X exchange, are remotely located in four of these regional offices and are connected by dedicated leased lines supplied by both BT and Mercury.

The exchange initially provides 12000 lines in London and 1000 lines spread between the provincial centres. It has sufficient processor capacity to support the current heavy traffic requirements resulting from the 'Big Bang' and any future growth that will be required. The number of lines in use has already doubled since last year.

The network already has the built-in capability for DASS II which will be offered shortly to Stock Exchange telephone exchange users, enabling them to have a wholly digital connection into the system. DASS II is a new digital signalling system enabling digital private branch exchanges to use common channel signalling to a System X exchange.

Message switch for Standard Chartered

Standard Chartered Bank has placed an order worth over £3M with Systems Designers p.l.c. for its System 400 Banking Message Switch, which runs on Tandem equipment.

The bank will use the System 400 to provide gateways on a worldwide basis to banking industry networks, national clearing systems, other public networks and the bank's own computer systems. The first three nodes will be installed in London, Hong Kong and New York by the third quarter of 1988. Interfaces will be provided to SWIFT, telex, the bank's private network, CHAPS, CHIPS, and the bank's mainframes. Future nodes have been proposed for Bahrain, Hamburg, Tokyo, Singapore and Kuala Lumpur.

The contract was awarded after extensive evaluation by both the bank's staff and the consultants Butler Cox. This included visits to existing user sites of System 400 and competing systems in London and overseas.

565Mbit/s European cable

Mercury Communications, France Telecom International and Companhia Portuguesa Radio Marconi (CPRM) have signed an agreement for an optical fibre submarine cable system linking the United Kingdom, France and Portugal.

The cables will terminate on the south coast of England, in the north of France, and near Lisbon. The direct England-France cable will be a multiple fibre unrepeatered link some 150km in length, one of the longest such links in the world. The cable connecting Portugal will be a repeatered system operating at a capacity of 565Mbit/s per fibre pair. This represents one of the largest capacity submarine links in the world.

Vodafone offers cellular on the p.a.b.x.

Vodafone cellular phones can become mobile extensions by means of a direct connection between the Vodafone network and the customer's p.a.b.x. or private branch network.

TELECOMMS TOPICS

While direct terminations at Vodafone exchanges have been in service for over two years, recent changes in the configuration of the Vodafone network allow the connection to be made to the nearest Vodafone base station. This new facility, known as Vodanet, reduces the length, and the cost, of the dedicated link.

Since calls through Vodanet are not switched at any point by either of the public telephone networks, the cost to Racal-Vodafone of delivering these calls is reduced. These savings are being passed on to the customer. Call set-up times, both from extension to mobile and vice-versa are also significantly reduced.

STC breaks submarine system record

What is believed to be the longest unregenerated optical fibre underwater telecommunications system to be won against competitive tender, has been successfully completed by STC. It is also believed to be the first commercial application of 1535 nanometre lasers for undersea telecommunications systems.

The lasers used in the terminal stations are distributed feedback single line lasers. These have a very narrow spectral width and thus much less dispersion over long transmission lengths.

The 90km armoured cable link between the Isle of Man and the UK mainland contains six pairs of optical fibres, five of which have been equipped to operate at 140Mbit/s.This gives a basic capacity of nearly 10 000 voice-grade circuits as compared with the 120 of the coaxial cable system that it supersedes.

The £3M contract placed by Manx Telecom and British Telecom includes the provision of the land-based terminal equipment. STC is currently manufacturing an even longer unregenerated optical fibre system. This is the 133km link between the south of England and the Channel Islands which is scheduled for completion at the end of 1988.

Low-cost earth station

Inmarsat, the International Maritime Satellite Organization, has approved the trial use of limited-capacity earth stations, designated L-CES, for the provision of telex services to ships and possibly other mobiles via its system.

These new stations, which will be adapted versions of Inmarsat Standard A ship earth stations, will have antennas less than 1 metre diameter and will cost less than $50 000. They could open up and simplify access to Inmarsat satellites, particularly for developing countries and from areas where the existing telecommunications infrastructure is inadequate.

BT aims to educate

As well as marketing certain of its in-house training courses outside the organisation, British Telecom has also produced a video, with an accompanying book, to provide an introduction to data communications.

A joint-housing in the 1.55 micron BT-Manx No.1 unrepeatered submarine optical fibre system, passing through the supporting guide tube on its path to the plough on the sea bed. This ensures low residual tension when the cable is laid and so prevents the cable unburying itself in sand-wave areas.

This latter, The Datacomms Connection, has been produced to educate newcomers and refresh practitioners on fundamentals. It should also be useful to senior management in view of the fact that business is becoming increasingly dependent on data communications. It is available through BT's BuyLines catalogue, price £120 + v.a.t.

BT's one-day Data Communications User Course has been specifically developed for users of personal computers who have a requirement to exchange data with similar systems – both nationally and internationally. The training methods employed include direct tuition, demonstrations and practical hands-on experience, with each course member having access to a personal computer. While obviously not being able to cover every contingency, this approach should give a prospective user an understanding of what can be achieved and the basic knowledge to get started. In addition, it gives an appreciation of the approach needed for fault diagnosis. More information from Joe Bulman, BTI External Course Manager on 01-936 4478.

Optical expo

Papers are invited for the Fourteenth European Conference on Optical Communications (ECOC 88). To be held from 11 to 15 September 1988 in Brighton, it will provide a major international forum for the dissemination of significant new results on all aspects of optical fibre communications – both scientific and technological.

In addition to the technical programme, for the first time there will be an associated exhibition. Original papers are invited on topics related to the theory, fabrication and characteristics of materials, passive components, active devices, fibres and cables, optical and optoelectronic integration, as well as systems and applications. Papers are also invited for two special 'highlight sessions' on photonic switching and intensity-dependent effects on fibres.

Abstracts should be sent to (and more information obtained from) ECOC 88 Secretariat, Conference Services, IEE, Savoy Place, London, WC2R 0BL, tel. 01-240 1871.

British Telecom digital mapping

British Telecom has embarked on a £19M digital mapping project to transfer records and maps of its inland cable network from paper to computer. BT has chosen Intergraph, which claims to be the world's largest cad/cam and digital mapping specialist, to be its sole supplier in the first phase of this major project. When ultimately completed it is expected to be the largest of its kind in the world.

In the first phase of the project, BT will supplement existing capacity with four DEC VAX computers supplied by Intergraph. These will serve approximately 110 workstations to be provided in BT operating districts. The computers will initially store maps and records of BT's cable networks in the principal towns and cities in each district. This first phase is expected to take about two years.

In the three-year second phase, the system will be extended to include all urban areas. It will be enlarged to include rural areas in the final stage.

UK contract for Telindus

Telindus Ltd, the UK subsidiary of the Belgium communications company of the same name, has won a contract worth £400 000 from East Sussex County Council to supply and install a new data network.

The new network will replace three separate, ageing communications systems which together serve 79 different establishments. When the scheme is completed in three years' time it is expected that it will cover all major towns in the county and reach 128 establishments. These will include social services offices, libraries, schools, and fire stations.

Telecomms Topics is compiled by Adrian Morant

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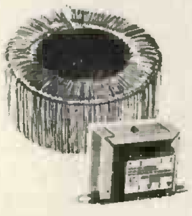

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7475A/002	A3 size six pen plotter with HP-IB interface	950
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TELEVISION BROADCAST

Eureka h.d.tv project

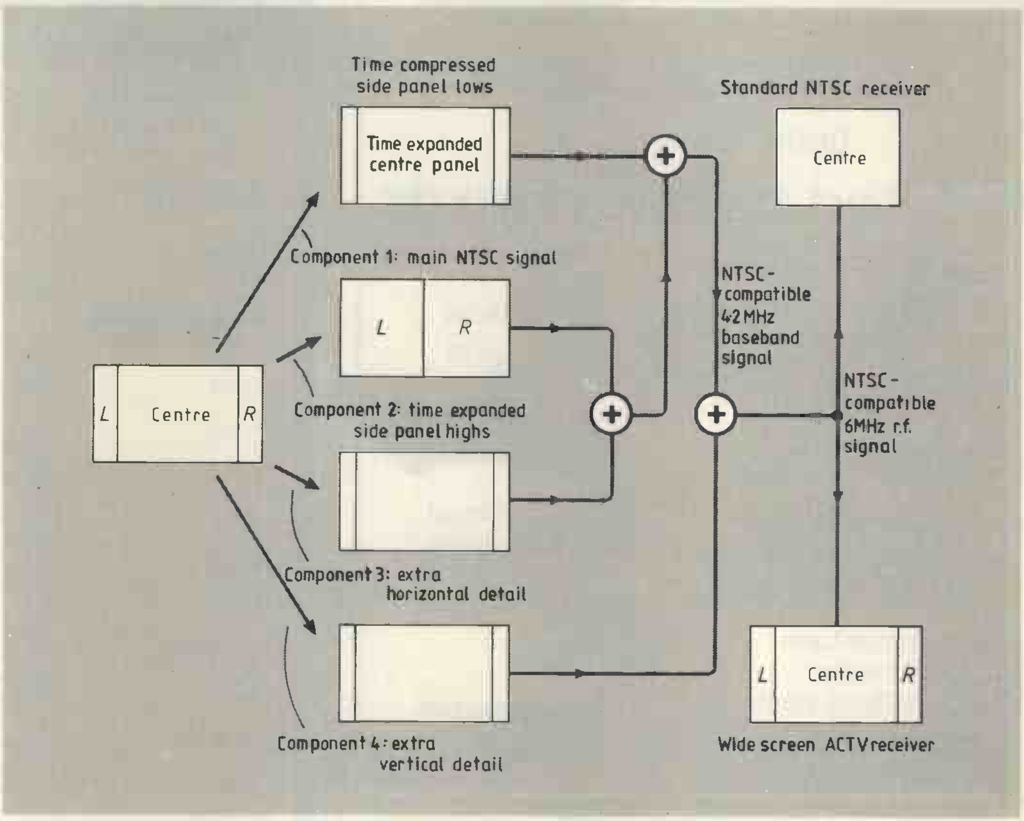
The DTI is providing funding of £2.5M to the BBC and IBA to assist in the demonstration and promotion of the compatible h.d. tv standard being proposed under the European Eureka EU95 compatible high-definition television system project in which the leading ("A") participants are Robert Bosch of West Germany; Philips of the Netherlands; Thomson of France; and Thorn-EMI of the UK, with the support of 25 other firms and organizations as "B" participants including seven UK members: BBC, British Telecom; IBA; ITVA; Quantel; Rank Cintel; and STC.

EU95 members are investigating an h.d.tv studio standard for Europe of 1250/50/2:1 for programme production aimed at the 50Hz world, and also an h.d.tv digital world production standard of 1152/50/non-interlace/ 16:9 aspect ratio with 1920 luminance samples per active line (960 samples for colour difference signals). This would, they believe, overcome the problems of the two (50/60) field rates, providing headroom for conversion to either 1250/50 or 1125/60 while satisfying the needs of cinema-like large screen presentation. They consider there to be strong arguments for a world standard based on 50Hz rather than 60Hz, claiming that the transfer to and from film would be superior; that, for a given bandwidth and interlace factor, 50Hz provides greater spatial resolution than higher field rates; and that (with a non-interlace system) motion portrayal is satisfactory with field rates of 50Hz or greater.

Teletext written off in USA?

The potential impact of new technology and new technical standards on television continues both to excite and divide broadcasters. This has been highlighted by the continuing debate on high-definition television (h.d.tv).

In the USA, the three major networks have split on h.d.tv: CBS, with Joseph Flaherty, has been a prime advocate of the Japanese 1125/60 standard for electronic production in order to phase out costly 35mm film production; NBC, which remains connected with the David Sarnoff Research Centre although this is now part of SRI, is linked with the recently announced "advanced compatible television" (ACTV) system which is being developed to provide 525-line compatible wide-screen pictures over a conventional single channel (with the potential of further enhancement to full h.d.tv through the use of a wider bandwidth or a second channel); while ABC, now owned by Capital Cities, remains to be convinced that any radical new systems are appropriate to the domestic broadcast medium, although accepting that some of the proposed compatible enhancement systems offer immediate potential for significant improvement in picture quality in the home, together with economic integration with existing facilities without recourse to wide-screen displays.



ACTV – an NTSC-compatible system providing wide-screen pictures over a single conventional channel.

Traditionally, ABC has tended to argue that broadcasters should always recognize the difference between "profitable innovation" and technically exciting but commercial inappropriate technology. In a "Point of View" article in the *SMPTE Journal* (October 1987), Max Berry and Robert Thomas of ABC insist that for the American commercial broadcasters "a prime example of inappropriate technology is teletext, a derivative of a dream of the late 1930s, whereby newspapers were to be delivered to the home by facsimile. Teletext was destined to fail in the US for two principal reasons. First, the public had faster access to better information without having to devote their undivided attention to a screen or become entangled with a complex menu-driven system that even many engineers found perplexing. Second, and even more decisive from the standpoint of management, was the inadvisability of furnishing a secondary broadcast service that might encourage viewers to tune away from the main programme channel, especially during commercial messages. In recognizing these innate deficiencies, Julius Barnathan avoided an enormous capital investment by ABC in a technology that was utterly inappropriate for the US market. For engineers, the legacy of teletext is, hopefully, a sense of respect for the business facets of new technology."

Historically, it was the decision of the BBC to go ahead with its Ceefax service in the mid-1970s – for which initially it expected there would be a supplementary licence fee – that persuaded the ITV companies (albeit reluctantly) to follow suit, subsidizing the Oracle service to the tune of millions of pounds until it became self-supporting (other than the subtitling service) during 1985.

Users of the effective British services would certainly not regard teletext as "inappropriate new technology" or agree that the public has other faster access to news and information. Rather that teletext is a prime example of the way in which a strong element of public service broadcasting and regulation can result in eventual commercial viability for an innovation that is likely to lose money in its early days.

Television Broadcast is written by Pat Hawker.

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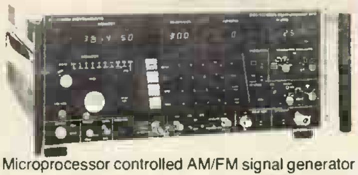

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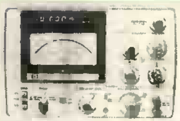

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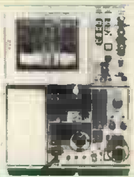

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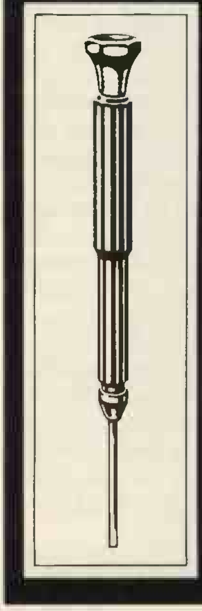

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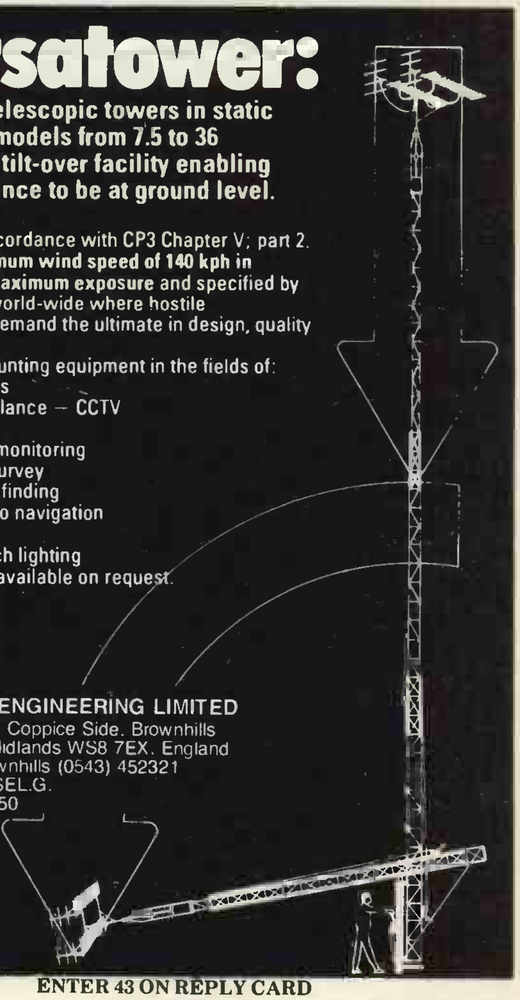

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RADIO BROADCAST

H.f. receiver front ends

The 'front end' design features of recent h.f. communications and broadcast receivers seem to have settled into a pattern that includes up-conversion to a v.h.f. first i.f., using a phase-locked-loop (p.l.l.) synthesized local oscillator and a passive ring diode mixer, with pre-mixer selectivity provided by a series of sub-octave filters. Such receivers have excellent frequency stability and, with digital read-out and memory, provide easy and accurate setting to a desired channel. Dynamic range, as a laboratory measurement, can be better than 90dB.

But increasingly it is being recognized that this form of front-end, unless implemented with sub-systems designed to the highest professional standards, results in some performance characteristics significantly below those achieved in the best receiver designs of the 1960s based on valves.

There is, as Ray Howgego, G4DTC, has pointed out, still a good case to be made for using thermionic devices for a cascode signal-frequency amplifier and the mixer stages of a high-performance receiver. He believes that in terms of cost-effectiveness, the little-known 7360 beam-deflection mixer is still an optimum choice: "Although now quite costly (about £15), it probably still represents best performance per pound". This RCA-developed valve appeared on the scene rather too late ever to be widely used in receivers. It was introduced in 1960 primarily for use as a balanced modulator in s.s.b. transmitters or as a product detector in receivers, but can function very effectively as a highly linear switched (commutation) mixer with excellent strong signal capabilities, low equivalent noise resistance and requiring relatively little local oscillator power.

While some passive diode ring mixers have good strong-signal performance they need a 1:10 ratio of signal power to oscillator power; about one watt of oscillator power for handling up to about 100mW of signal power.

A dramatic improvement on the passive diode ring mixer is now offered by the recently introduced passive silicon fet ring mixer, pioneered by the Siliconix integrated device Si8901, and offering further potential improvement in the form of a gallium arsenide passive fet ring mixer which, to quote Robert Zavrel, W7SX (*Ham Radio Magazine*, November 1987) "could add another 7dB or so increase in third-order intercept point".

In 1986, Ed Oxner of Siliconix noted that the paralleling of diodes in the better diode ring mixers in order to achieve greater current handling had led to the need for a massive increase in local-oscillator power. With a passive fet commutation mixer, gate voltage rather than forward biasing current turns the switches on and off. With the higher gate impedances, oscillator power can be dramatically reduced, with only about 25mW of power needed to switch 100mW of r.f., thus in effect giving to solid-state the advantages of the beam-deflection valve (without the problem of susceptibility to magnetically induced hum). Ed Oxner achieved with the silicon Si8901 third-order intercept points of over 40dBm with less than 20dBm of oscillator power.

The better valve designs of the 1960s often used permeability-tuned oscillators providing both stability and a low-noise spectrum. Such receivers could thus achieve a good close-in dynamic range; overloading from strong off-frequency carriers was reduced by the use of high-Q pre-mixer signal-frequency tuned circuits, ganged-tuned with mechanically variable capacitors rather than the modern lower-Q electronic tuning diodes.

Spectrally-pure and jitter-free p.l.l. synthesizers, needed to overcome the effects of reciprocal mixing, are rare except in a few very high-cost designs. The performance of permeability-tuned oscillators of the 1960s "remains difficult if not impossible to duplicate with p.l.l. synthesizers" Zavrel points out, although he suggests that the recently described 'direct digital synthesis and numerically-controlled modulated oscillator' (Earl McCune, R. F. Technology Expo, February 1987) holds great promise as a replacement for p.l.l. synthesizers, offering almost instantaneous frequency changes, free of p.l.l. lock-in time – "but more work is needed to achieve the necessary low spectral noise densities demanded from h.f. local oscillators."

In his recent design of a high-performance receiver for broadcast and communications reception, Ray Howgego felt that p.l.l. synthesized oscillators, with all their problems, should be avoided like the plague. Instead, he used a balanced Kalitron tunable oscillator, tuning 4.4 to 34MHz in ten switched bands and using a pair of 2N5458 fets buffered by a pair of 2N3866 bipolar transistors. After an initial switch-on drift, this remains stable within 20Hz for an indefinite period.

Vasil Uzunoglu (Synchtrack, formerly Fairchild) and M. H. White (Fairchild) have recently been drawing attention to the useful features of synchronous tracking oscillators (shades of Professor Tucker's 'Synchrodyne' receivers of 40 years ago) as an alternative to p.l.l. or Costas loops and as overcoming the instability and poor selectivity of the regenerative detector (a.m./a.m. converter) while retaining, as an a.m./p.m. converter, the regenerative detector's property that its sensitivity is inversely proportional to the input signal level. Whether the synchronous tracking oscillator could overcome the disadvantages of p.l.l. frequency synthesis in high-performance receivers remains to be seen.

What price a.m. broadcasting?

The BBC is being forced by irate listeners to defend its plan to concentrate its main domestic radio networks on to v.h.f./f.m. over the next few years, creating an 'events network' on its long-wave, now 198kHz, channel and eventually dropping its Radio 3 medium-wave outlets. The BBC points out that it hopes to carry 90% of all Radio 4 programmes as a sustaining programme on its events network, though one wonders how this will be viewed by those in Government advocating the elimination of 'simulcasting'.

From a technical point of view, there is no doubt that v.h.f. in its primary service area is vastly superior for music, but the BBC is laying it on a bit thick in its annual report in claiming that "medium and long wave offer only a pale apology of the v.h.f./f.m. signal quality; the bandwidth is barely 5kHz, compared with some 15kHz; the dynamic range is limited; there are no stereo transmissions; and in many areas interference is a serious problem, particularly after dark."

In practice, only a small minority of domestic, portable and car-radio receivers is capable of taking full advantage of the f.m. signal and many are used with inadequate aerials. For a great many listeners, for speech-orientated channels such as Radio 4, m.f./l.f. provides entirely acceptable quality from ferrite-rod or car aerials at distances or in sites unsuitable for v.h.f. reception on mono, let alone stereo.

For both broadcasters and listeners, m.f./l.f. is an economical system. Indeed the BBC report notes that running costs can be further reduced by such techniques as dynamic carrier control which has been designed to reduce electricity consumption at m.f. transmitting stations by reducing the transmitted carrier power during loud passages, the inverse of the old controlled-carrier systems that raised output power to cope with peaks of modulation. The BBC points out that every radio set has an automatic gain control circuit (thanks to H. A. Wheeler's invention of January 1926) which compensates for variations in received signal levels, so listeners are unaware of the reduction in transmitter power. Tests on the Radio 2 transmitter at Brookmans Park show that significant energy savings can be made without affecting the quality of service.

Radio Broadcast is compiled by Pat Hawker.

NEW PRODUCTS

Control system designer on a PC

Educational and professional use is intended for the Codas control design and simulation program which runs on any PC-compatible computer. Consisting of two subsystems; 'controller' and 'plant', the program allows the entering and editing of control functions in time, frequency or other parameters and will display open and closed-loop time responses in Bode, Nyquist or Nichols plots.

A window facility allows any two plots to be displayed at the same time and the software has the ability to switch between plots to show the before and after effects of using a control compensator. Time delay can be introduced with its effects reflected throughout the system. The program comes with a comprehensive manual and includes a tutorial.

Complementing the Codas program is another, PCS, for process control simulation with many similar facilities. The programs are available as one-off for single users or multi-user licences are available for educational or training establishments. Golten & Verwer Partners, 33 Moseley Road, Cheadle Hume, Cheshire SK8 5HJ. Tel: 061 485 5435.

Signal generator with counter

An integral digital counter is incorporated into the GFG-813 function generator. Frequencies ranging from 100Hz to 13MHz give the instrument applications from radio and tv test and repair to laboratory, prototyping and production work.

In addition to sine, square and triangular waves, the unit provides sweep and toneburst outputs which may be gated or triggered. Amplitude and frequency modulation is provided. Main output is 20V peak-to-peak into an open circuit or 10V into a 50Ω load at 1kHz. Flight Electronics Ltd, Ascupart Street, Southampton SO1 1QL. Tel: 0703 229041.

Precise temperature controllers

An extensive choice of variations is available with the Rex range of microprocessor-controlled temperature controllers. Perhaps the greatest advantage is their small size. Controllers are often the deepest item on an instrument panel and the whole panel needs to be made bigger to accommodate them. Rex controllers are only 100mm deep behind the bezel which is a third of the size of rivals.

Built-in microprocessor control gives the instrument a very wide range with automatic programming for a variety of thermocouples, platinum probes and thermistors. Calibration is automatically carried out twice a second. Accuracy is better than 0.25%. Many options include RS422 serial link, self tuning, remotely programmable set points and alarm levels, and a variety of outputs; heater and cooler controls and valve motor drives. TC Ltd, PO Box 130, Uxbridge UB8 2YS. Tel: 0895 52222.

Switchmode power family

Outputs range between 30 and 800W in the family of switch-mode power supplies from STC. Each model is mechanically compatible with other standard supplies, although a higher performance is claimed for supplies occupying the same space as rivals. Compliance with international safety standards is included.

An efficiency of 70% is guaranteed on all models, which have a wide choice of output voltages and dual mains input, 110 and 220V. These power supplies are particularly suitable where low noise and heavy-current power sharing equipment is used, such as computer peripherals. STC Components, Edinburgh Way, Harlow, Essex CM20 2DE. Tel: 0279 26811.

Twice as many i/o lines on STEbus

The use of a Zilog counter-timer and i/o controllers has allowed a single card to provide 80 input/output lines, effectively doubling the number normally available on an STE card. Lines are organized as eight 8-bit and four 4-bit ports.

Support for vectored and non-vectored interrupts allow the SP800 card to be used in various applications including real-time control. If required, a signal conditioning card, which provides opto-isolation, is available. DSP Designs Ltd, 100 St Pancras Way, London NW1 9ES.

Time key for software protection

Software can be licensed for a specific timespan and protected against piracy through the use of TimeKey from Dallas Semiconductors. The key stores passcodes to use the software and is internally programmed to self-erase its memory after a specific time period of between a day and two years. TimeKey is used in conjunction with KeyRing which fits the computer parallel port without affecting the operation of the printer. Plugging the key into the receiver identifies the authorized user and 'unlocks' the software.

The key can be used with any IBM PC or clone and does not prevent legitimate copying of software, such as transferring it to hard disc. However, any such copy needs the key to be accessed. Four sections on the key's memory contain: communication protocol; a software identity code; the programmed password and 384 bits of additional memory that can include further protection software. All the information is randomized so that it is impossible for anyone without the keyword to decode the contents of the key. Available througfh Joseph Electronics Ltd, 2 The Square, Broad Street, Birmingham B15 1AP. Tel: 021 643 6999.

High-speed power op-amp

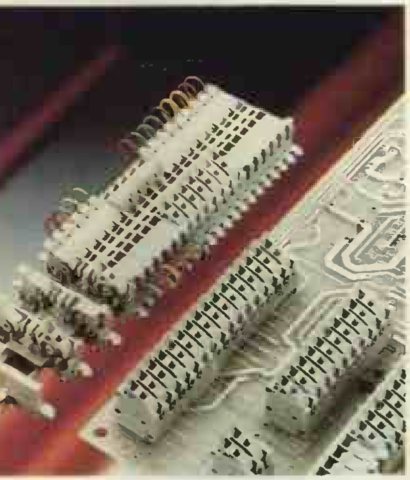
Speed and power are combined in the TP1465 op-amp from Teledyne Philbrick. This operates from a ±15V to ±40V supply and can provide output voltages up to ± 34V at ±750mA. With 125dB open loop gain, 2.5GHz gain-bandwidth product, and 1000V/μs slew rate, two versions have differing temperature ranges.

Typical applications include highly accurate audio amplifiers, video distribution amplifiers and yoke drivers, drivers for test equipment, and for inductive and capacitative loads. Available through MCP Electronics Ltd, 26 Rosemont Road, Alperton, Wembley, Middlesex HA0 4QY. Tel: 01-902 6146.

NEW PRODUCTS

Terminals for p.c.b. connection

No tools are needed to connect wires into these Turn-o-lock terminals. Contact is made by insulation displacement when the locking lever is turned. Any number of the connectors may be stacked side by side and end covers are optional extras. Each module has a test point for the introduction of a 2mm probe or test headphones. Contacts are tin-coated phosphor bronze. Each contact can cope with a nominal current of 4A at 50Hz with a voltage rating of 2.5KV. Valley Microelectronics Ltd, 5 Langley Business Court, Beedon, Newbury, Berks RG16 8RY. Tel: 0635 248111.



Hard-disc expander

Memory capacity on a hard disc can be more than doubled by using the Konan KXP-230Z. It uses half a slot on a PC and may be used with the majority of disc drives.

When the card is installed an expanded disc is created automatically. It is partitioned into an MS-DOS section with the KXP's own software and the remaining partition is the expanded disc. Typically a 20Mbyte disc will have a 1Mbyte DOS section with up to 38Mbytes in the Edisk (expanded) partition. High-capacity discs, up to 302Mbytes can be further partitioned into 'volumes' or treated as a single volume. Built-in 'intelligence' notes the files most regularly accessed and keeps them loaded in a cache area for instant access.

Data is compressed but stored in the normal MFM format without run-limited formatting. Disc errors are automatically corrected by the built-in error-detection facility, and a fragmentation control allows data to be added to a file contiguously, rather than in the next available disc location. Further details from Prudential Computer Solutions, Unit 9, HPCC, Harrow Road, London NW10 0RG. Tel: 01-965 829

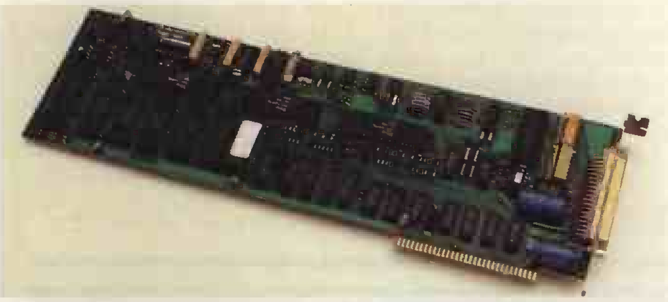
Interface card for PC includes Z80

On-board processing allows the Alpha Super Card to run independently of its host computer. Its functions include eight analogue inputs and four analogue outputs, four relay drivers and 16 logic-level input/output lines.

All functions and the 40Kbyte of buffered memory are controlled through a Z80 processor which can be set to undertake specific tasks and left to get on with it. Data can be downloaded to the host at convenient breaks in the program currently running.

With 16-bit accuracy and programmable sampling time the analogue inputs can have set limits, gain and sampling sequences. Analogue outputs can be used to generate low-frequency waveforms and ramps independent of the computer. Comparator functions are also easily programmed.

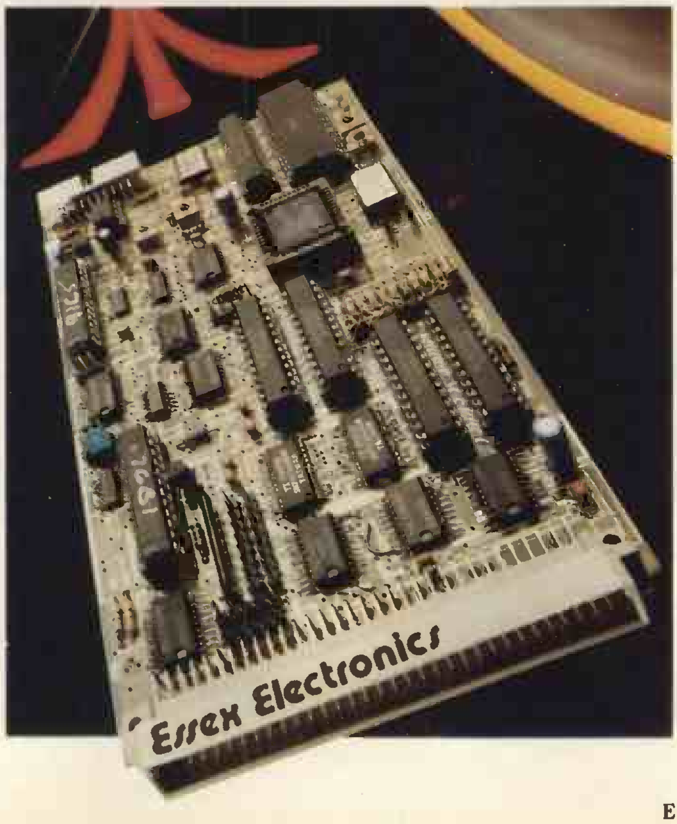
The card is controlled through a series of simple commands which may be sent from the host running in any language. The equivalent of OUTPUT "F10,G10,I0,I1,T" will set input channels 0 and 1 with a gain of 10 and f.s.d. of 10V. Further details from CIL Group, 4 Wayside, Commerce Way, Lancing, West Sussex BN15 8TA. Tel: 0903 765225.



Signal processing on the STEbus

Typical applications for the Trident 320 digital signal processing card are adaptive line filtering, digital filtering, speech processing, optical character recognition and industrial robot control. Incorporated on the single Eurocard are 12-bit d-to-a and a-to-d converters and a TMS 32010 processor, running at 20MHz. The card operates as a slave on the STEbus and features dual-ported ram and a 16-bit communications port.

Fast real-time mathematical manipulation are a feature of the card which can perform Fourier transformation at high speed. A 16 by 16-bit multiplication takes only 200ns. Such processing power can be of use as a maths co-processor in conjunction with a master processor on the STEbus. With this in mind, Essex Electronics have made the card available without analogue interfaces. Essex Electronics Centre, University of Essex, Colchester, Essex C04 3SQ.



A straight guide to enclosures

Calculating and drawing electronic packaging has been made easier by Vero who has produced a rule graduated in the U and HP units used in designing enclosures. It has an overall length of 9 U or 84 HP and also has a metric scale (440mm). It is made from anodized aluminium and costs £2. BICC-Vero Electronics Ltd, Flanders Road, Hedge End, Southampton S03 3LG. Tel: 0703 266300.

Graphics supercomputer

Operating at over 200 mips, the Reality graphics computer can manipulate 15 million pixels/s. This makes it possible to calculate over 100,000 three-dimensional transformations/s, including colour shading and hidden-surface removal. All this is possible through the use of the Inmos T800 Transputer which gives it both the high-speed ability of the entry-level computer and the ability to upgrade to an even higher performance by the addition of further cards with more transputers.

First in the system comes a frame store board which can store up to 2M pixels, or four complete images. Each board has a 12-bit in/24-bit out colour look-up table to display 4096 colours simultaneously from a palette of 16.7 million. If a true-colour image is required, three framestore boards are used together to provide 256 shades of red, blue and green with four overlay planes for each channel. A frame-grab input on each channel is standard for real-time video digitizing. Virtual images can be larger than the screen to allow panning and zooming. Buffered framestore images allow one to be displayed while another is being loaded. Rapid switching between the buffers give real-time animation. For three-dimensional digital images, and additional Z-buffer board holds the depth information for all the framestore boards in the system.

Further processing power is provided by a geometry card which consists of a 'pipeline' of processors (between 12 and 20 Transputers) which can process such complex geometries as shading an image according to the position of simulated light sources. The geometry processor is also used to improve the rendering of an image.

All the cards in the system are VMEbus compatible. The makers, Real World Graphics, have previously concentrated on add-on graphics cards for IBM PC and AT computers. The Reality machine is claimed to be the first British graphics supercomputer. Real World Graphics Ltd, 5 Bluecoats Avenue, Bluecoats, Hertford SG14 1RB. Tel: 0992 554442.

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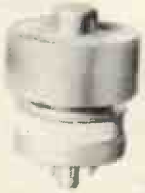

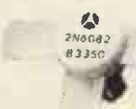

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ENTER 47 ON REPLY CARD

NEW PRODUCTS

Megabit eeprom

Hybrid circuitry on a ceramic substrate produces a one megabit eeprom module that is pin-compatible with standard 1Mbit eproms. It is configured as a 128 by 8-bit device with byte or page-mode write cycles, allowing up to 64bytes to be written in 10ms. Access times between 250 and 350ns are available in different versions. HMEE48128J can cope with a minimum of 10,000 erase-write cycles and retain data for ten years. Hybrid Memory Products Ltd, Elm Road, West Chirton Industrial Estate, North Shields, Tyne and Wear NE29 8SE. Tel: 091 259 0997.

Low-pass video filters

Passive high-frequency filters are designed to minimize interference from out-of-band signals by band limiting, frequency separation and interference suppression.

Video low-pass filters in the Lexor range are based on seventh-order Cauer filter designs incorporating high-stability inductors to provide sharp cut-off and low ripple in the pass band, while providing return-loss characteristic to match external equipment. Filters are manufactured in a range from 0.5MHz to 20MHz. Active Electronic Laboratories Ltd, Turriff Building, Budbrooke Road, Warwick CV34 5XJ. Tel: 0926 499019.

Four-channel push-pull driver

Loads of up to 600mA can be driven by the CD-293 i.c. of Cherry Semiconductors. Each of the four channels is controlled by a t.t.l.-level logic input which has a separate power supply input to reduce power dissipation. Each full-bridge driver has an enable input which switches all four resistors. Output clamping diodes allow the driving of inductive loads. Available from Clere Electronics Ltd, Kingsclere, Newbury, Berks RG15 8NL. Tel: 0635 298547.

Heat-resistant ceramic capacitors

High-voltage ceramic capacitors from ICC can operate over the full military-specification temperature range. Values between 10pF and 33000pF are available. Use of NPO dielectric keeps the temperature coefficient within ±30p.p.m. over the complete operating range, and also ensures stability under extreme d.c. bias, high frequency and ageing. Integrated Ceramic Components Ltd, 9B Intec Two, Wade Road, Basingstoke, Hants RG24 0NE. Tel: 0256 460746.

Teletext on a PC

Ceefax and Oracle broadcasts as well as other data services incorporated into the tv signal can be received and decoded by a plug-in card for the IBM PC. Software supplied with the card is menu-driven and is compatible with colour and monochrome screens. Pages of information can be stored, retreived from disc and printed. The system also enables a Prestel-like database to be created and updated.

The TD 400 board only needs a tv aerial to be complete and will work with the majority of PC-compatible computers. Metrotel Viewdata Systems Ltd, Argyle House, Joel Street, Northwood Hills, Middlesex HA16 1TU. Tel: 09274 28573.

Printed-circuit plotter uses laser

High accuracy is promised to users of the L1 photoplotter which can be interfaces to a number of p.c.b. cad systems. An argon-ion laser emits a blue light which is focussed with an accuracy of 10μm, providing an accuracy of 2540 dots/in. Low-cost orthochromatic film is held on the inner surface of a drum and the laser beam is reflected by a rapidly rotating mirror which moves along the drum, providing a raster scan. Only two moving parts are involved; the mirror and the linear positioning carriage. Film is exposed within five minutes, independent of size. Three processors are used internally to control the plotter which accepts RS274 (Gerber) photoplotter data and performs the translation into raster format. Electronic Industrial Equipment UK Ltd, Midland House, Halesowen, West Midlands B63 3HY. Tel: 021 550 9758.

Bit-slice and microprogram designs system

Bit slice design is the main method of designing high-performance processors. One key feature of bit-slice microprogrammed systems is the user defined architecture. This permits a huge range of configurations with microcode memory access speeds down to 10nsec and up to 512 bits wide. Step Engineering supplies development systems to cater for this range. The Step 50 debug station complements the Step Engineering range by providing a cost effective solution for small to mid-range computers.

The target system microcode is simulated in a control store, up to 160 bit wide and 4K deep with 25ns access. The debug station also includes clock control and high speed trace facilities, 80 bit wide and 4K deep at 25MHz. The clock and trace are controlled by a comprehensive logic state analyser with multi-level triggering and 80 bit qualifiers. As with other Step Engineering systems the MetaStep language provides high-level instruction definition and assembly of microcode.

MetaStep language system provides high-level language features and still gives control at the bit-vector level. It copes with pipeline delay compensation and design rule management. The control store editor provides full symbolic display of microcode including disassembly to the user-defined mnemonics. The trace display can be disassembled in the same way. Monitor mode makes execution control commands available to the designer to run (execute) the microprogram, halt, single step and run to a breakpoint.

The whole debug station is controlled by an IBM PC/AT running under Microsoft windows to enhance the display of system functions. Debug facilities can be selected from menus. Data from different tasks can be presented simultaneously in multiple windows improving efficiency and productivity.

Step Engineering systems are available through Thame Microsystems Ltd., Thame Park Road, Thame, Oxon OX9 3XD. Tel: 084 421 7272.

Pick-and-place for surface mount

Automatic pick-and-place machines for surface mounted components can be prohibitively expensive for the smaller company. Manual assembly with tweezers and glue is very fiddly. A nice compromise is offered by the Sumopolar 1 which is a manually-operated pick-and-place machine.

Polar coordinates are used to move the arm which can pick up components from cylindrical containers carried in a rotating table and place them on the p.c.b., which is held in place by an adjustable frame.

The suction head at one end of the arm is balanced by a glue dispenser at the other so that both operations are contained within the unit. The suction head can be augmented by a rubber sucker which can cope with larger components.

Tape-mounted components can be used with the machine which can also be adapted to take stick-fed pieces. Complementing the machine is a portable storage unit which holds up to 321 of the cylindrical containers, thus providing a wide range of components ready for a specific application. ECC Electronics Ltd, 9 Blenheim Road, High Wycombe, Bucks HP12 3RT. Tel: 0494 36113.

Chip-carrier sockets

The use of TI's CPR sockets enable p.l.c.c. components with 0.05in pitch to fit onto a standard 0.1in p.c.b. matrix. Three types available have 44, 68 and 84 pins and may be assembled manually or automatically with an orientation index for robot assembly. Other features are a very wide operational temperature range, a totally gas-tight seal, shock and vibration resistance and low insertion force for the components. Available through VSI Electronics Ltd, Roydonbury Industrial Park, Horsecroft Road, Harlow, Essex CM19 5BY. Tel: 0279 29666.

NEW PRODUCTS

Power distribution switched sequentially

Computer equipment needs to be switched on in a sequential order to operate correctly. A hard-disc drive, for example, needs to reach operating speed before it can be accessed by the computer. Kleanpower is a system that will switch on each peripheral in order with a 10s delay between each. Whichever device is the slowest becomes the 'key' equipment and switching this on will automatically power three other items in sequence. Sequential power-down works in a similar way. Each Kleanpower unit consists of four 13A-type power sockets with a lead and a 13A plug. Lightning Eliminations Ltd, Bandet Way, Thame, Oxon OX9 3SJ. Tel: 084 421 3204.

Lithium battery with 9V

Twice the life of an alkaline battery is offered by a new 9V lithium battery from Kodak. In addition, the shelf life of up to ten years compares with the two-to-three years of the alkaline.

Kodak has taken great care to make the battery safe, both in manufacture and in use, and leakproof. Its long life makes it particularly suitable for long-term use, in alarm systems, for example. Lithium batteries are also lighter than their alkaline equivalents. Kodak Ltd, PO Box 66, Hemel Hempstead, Herts HP1 1JU. Tel: 0442 61122.

Microwave digital telephone link

Line-of-sight communications for up to 20km is offered by the NEC LDR (local distribution radio) system. Microwave communications at 2MBit/s on one or two channels can be used as a permanent or temporary link to a p.a.b.x. Three units, a 600mm dish, a pole-mounted 13GHz transmitter/receiver and an indoor baseband unit, make up the system. LDR is compatible with BT's Megastream digital network and can be used for digital voice, video and data. NEC Business Systems (Europe) Ltd, 1 Victoria Road, London W3 6UL. Tel: 01-993 8111.

Compact disc coder for testing players

Simulation of a compact-disc laser pickup signal is provided by the Kenwood DA-3531 CD encoder. Radial and focus error signals are used to align the mechanism and modulated audio signals test the audio-frequency band characteristics of a CD player. Nine test patterns in the audio section are used to check emphasis function, crosstalk between channels and i.m.d. Subcode and error patterns are available for testing the digital operation of the player.

16-bit precision and low distortion are claimed for the test patterns which provide encoder outputs for testing the d-to-a converters and low-pass filters. Available from Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs PE17 4BG. Tel: 0480 63570.

No sweat in strain measurement

Two strain-measurement bridges are claimed by H. Tinsley to be easy to use and offer accurate measurement. Single-channel operation is offered by Sterling, which can operate for up to 40 hours on an internal rechargeable battery or from the mains. A range of ±19999 microns/m (Tinsley calls them microstrains) is covered.

Ten bridges are provided in the Sovereign model and the single display may be switched between the channels. Common to both models is the direct reading of strain and high temperature stability. Both operate in ½, ¼ or full bridge configuration. H. Tinsley and Co. Ltd, Standards House, 61 Imperial Way, Croydon, Surrey CR0 4RR.
Tel: 01-681 8431.

Low power eproms

C-mos versions of 256K and 512Kbit eproms offer much lower power consumptions than their n-mos equivalent. These from Advanced Micro Devices offer a 70% power reduction in active mode and a 92% reduction in standby. Access times down to 200ns make the eproms suitable for use with the newest high-speed processors. Low power consumption allows the devices to be used in compact and portable systems.

Two versions of the eproms are available; with windows for eprom erasure or without windows for one-time programming. Called the Am27C256 and 27C512, the devices are made by Advanced Micro Devices (UK) Ltd, Goldsworth Road, Woking, Surrey GU21 1JT. Tel: 048 62 22121.

Single-axis motion control

Many functions are incorporated into a single-card indexer for motion control. Velocity, position, status reporting and many other parameters can be programmed. Local processing relieves the host computer of many tasks. Handling of velocities, in the range of fractions of a step to over a million steps in a second is possible. With a similar range in acceleration rates, the board can be programmed with a complex move program. As many as 50 separate moves or 15 multiple-move sequences can be stored on the card. Self-test routines are included.

Model 1811, as it is called, connects directly to the system bus of a host processor and fully conforms to the IEEE-796 Multibus standard. Standard outputs include step pulse, direction and a shut-down function; inputs include 'home' and end-stop limits. Other functions may be defined by the user and include separate machine-control functions with trigger inputs to monitor external events. Two extra outputs can be used to trigger secondary operations. Direct-drive motors, servos and other positioning devices can be controlled, and the card can interface to a joystick for real-time position control. Parker Digiplan Ltd, 2k Balena Close, Creekmoor, Poole, Dorset BH17 7DX. Tel: 0202 690911.

Off-air frequency standard at 198kHz

BBC's longwave transmitters changed their carrier frequency to 198kHz on the first of February.

A new receiver has been designed for fixed installation in standard frequency distribution systems for the checking of atomic standards or quartz-crystal standards, although it can also be used itself as a standards unit. R.f. outputs at 10MHz and 5MHz or 1MHz are locked to the transmission by techniques which minimize phase shift.

The unit is designed by HCD who provided the BBC with the equipment to transmit the signal. HCD Research Ltd, 179 Junction Road, Burgess Hill, West Sussex RH15 0JW. Tel: 04446 2967.

Convolution – time-domain signal processing

In part two, Howard Hutchings describes the digital system equivalent of a first-order low-pass filter.

HOWARD J. HUTCHINGS

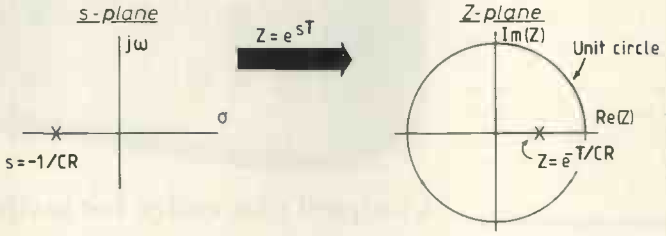


Fig.6. A digital system equivalent of the first-order low-pass filter can be derived from the pole position of the system impulse response.

Having discussed convolution in general in the last article, I will now describe the digital-system equivalent of the first-order low-pass filter.

Under the z-mapping, the system pole given by $s=-1/CR$ has been transformed from the left-hand stable region of the s-plane, to a point on the positive real axis of the z-plane located inside the unit circle[2], Fig.6.

The transfer function of the digital system is given by,

$$H(z)=\frac{1/CR}{z-\alpha}$$

where,

$$\alpha=e^{-T/CR}$$

To obtain a recurrence relationship from the transfer function,

$$\frac{y(z)}{x(z)}=\frac{1/CR}{z-\alpha}$$

$$y(z)(z-\alpha)=1/CRx(z)$$

$$zy(z)-\alpha y(z)=1/CRx(z).$$

As usual interpret z as a unit advance so that the recurrence formula is given by,

$$y(n+1)-\alpha y(n)=1/CRx(n)$$

and finally,

$$y(n)=\alpha y(n-1)+1/CRx(n-1)$$

Notice that current output $y(n)$ is the sum of weighted versions of the previous output $y(n-1)$ and previous input $x(n-1)$. This is an illustrative example of a system with digital feedback; as with all feedback systems care must be exercised to ensure that it is stable.

A system which calculates the current output using one or more previous outputs is called recursive. Recursive systems arise when the transfer function has poles situated other than at the origin of the z plane.

This particular system can also be realized non-recursively by expressing the transfer function as a power series,

$$H(z)=\frac{1/CR}{z-\alpha}=\frac{1}{CR}(z^{-1}+\alpha z^{-2}+\alpha^2z^{-3}+\ldots$$

Coefficients of successive terms make up the impulse-response sequence which completely characterizes the behaviour of the system. Alternatively, the impulse response is obtained from the recurrence relationship with a unit pulse input[3].

In an attempt to simplify the arithmetic let time $CR=2.0s$ and sampling period $T=1.38s$. This gives the recurrence relationship in a neater form and ensures a d.c. gain of unity.

$$y(n)=0.5y(n-1)+0.5x(n-1)$$

Using the recurrence relationship in the advertised form it is instructive to examine the shape of the processed output when input signal $x(t)=e^{-0.5t}$ is sampled every T seconds.

Table 1. A convenient method of representing the history of the input signal as it is processed by the filter.

Sample number n	Previous input x(n−1)	Current input x(n)	Previous output y(n−1)	Current output y(n)
0	0	1.000	0	0
1	1.000	0.501	0	0.500
2	0.051	0.251	0.500	0.501
3	0.251	0.126	0.501	0.376
4	0.126	0.063	0.376	0.251
5	0.063	0.032	0.251	0.157
6	0.032	0.016	0.157	0.094
7	0.016	0.007	0.094	0.055
8	0.007	0.004	0.055	0.031
9	0.004	0	0.031	0.018
10	0	0	0.018	0.009

Using the discrete form of convolution confirms the results shown in Table 1. To evaluate y_n, the output of the system after n conversions, a systematic approach is required. In Table 2 the rows represent the response to the input sequence x_0, x_1, x_2, x_4 respectively. The columns show the terms present at times $t=0$, $t=T$, $t=2T$, etc, Fig.8. Response y_n is simply the sum of the terms in the nth column.

Within this algebraic jungle exists a very simple pattern. To find the convoluted response, simply reverse the impulse response, aligning it so that h_0 and the sample of current interest x_n are coincident. The ordered weighted products will then follow automatically.

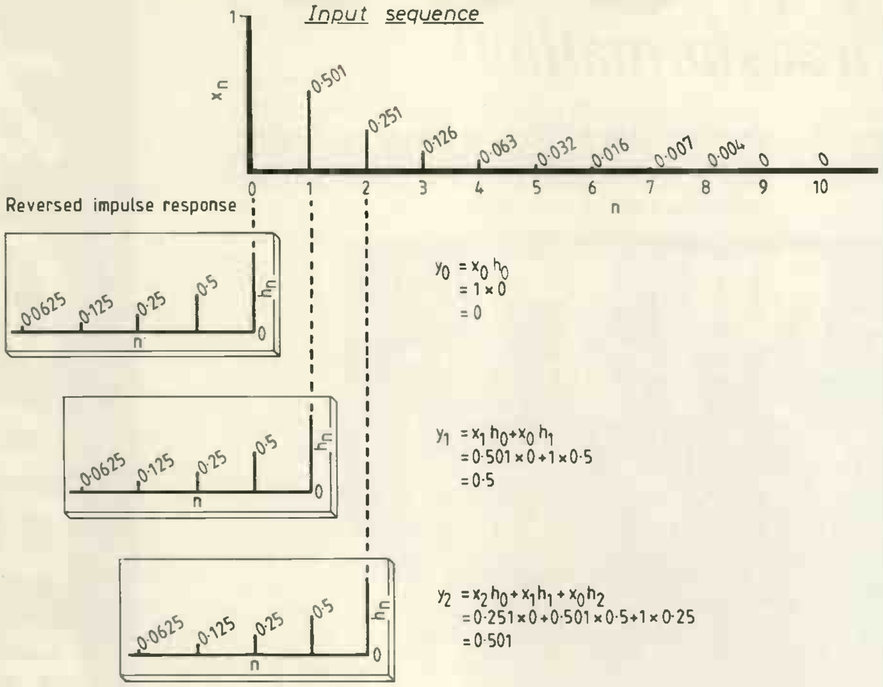
A numerical example may help. To find the rest of the terms in the sequence, continue moving the reverse impulse response to the right until none of the samples of the two sequences overlaps. My results are:

y_0 =0
y_1 =0.5
y_2 =0.501
y_3 =0.376
y_4 =0.251
y_5 =0.157
y_6 =0.094
y_7 =0.055
y_8 =0.031
y_9 =0.018
y_{10}=0.009

Table 2. Evaluation of system output y_n after n conversions needs a systematic approach.

t=0	t=T	t=2T	t=3T	t=4T	Response due to
x_0h_0	x_0h_1	x_0h_2	x_0h_3	x_0h_4	x_0
	x_1h_0	x_1h_1	x_1h_2	x_1h_3	x_1
		x_2h_0	x_2h_1	x_2h_2	x_2
			x_3h_0	x_3h_1	x_3
				x_4h_0	x_4

Column	Sum
1	$y_0=x_0h_0$
2	$y_1=x_0h_1+x_1h_0$
3	$y_2=x_0h_2+x_1h_1+x_2h_0$
4	$y_3=x_0h_3+x_1h_2+x_2h_1+x_3h_0$
5	$y_4=x_0h_4+x_1h_3+x_2h_2+x_3h_1+x_4h_0$



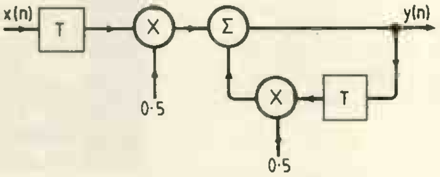


Fig.7 System block diagram of the digital filter representing the recursive relationship $y(n)=0.5y(n-1)+0.5x(n-1)$.

Fig.8 Graphical convolution of the input signal and impulse response is achieved by reversing the impulse response under the sample of current interest. The sum of the coincident cross products is the convolution of that sample and the impulse response of the system. The procedure should be repeated at each sampling instant by moving the impulse response too the right until none of the samples overlaps.

CONCLUSION

Time domain convolution is a fundamental operation which provides a basis for more advanced signal processing applications. For example the analogue form of convolution integral,

$$x(t)*h(t)=\int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$

bears a remarkable resemblance to the finite form of the auto-correlation function,

$$r_{xx}(\tau)=\int_{-\infty}^{\infty} x(t)x(t+\tau)dt$$

To obtain the auto-correlation function by signal-processing methods, the signal x(t) must be multiplied by a time-shifted version of itself $x(t+\tau)$ and the product then averaged. The result, an even function of τ, gives a measure of similarity between the original and time-shifted pulse.

A less esoteric description of the auto-correlation function is obtained by making τ equal to zero, in which case $r_{xx}(0)$ is equal to the mean square value of the pulse. This apparently unconnected signal-processing operation is in fact closely related to the convolution integral.

Notice that if the characteristics of the time reversed impulse $h(t-\tau)$ are made identical to the characteristics of time-shifted pulse $x(t+\tau)$ then the operation of convolution is identical to that of auto-correlation[4].

References

2. Hutchings, H.J., Digital filters explained, *Electronics and Wireless World*, December 1985, p.23.
3. Hutchings, H.J., Closing the loop (practical closed-loop control), *Electronics and Wireless World*, December 1987, p.1222.
4. Meade, M., Electronic Signal Processing. T326, Open University Press 1984.

Howard Hutchings is a senior lecturer with Humberside College of Higher Education and a part-time tutor with the Open University.

In the first part of this article, in the February issue, the lower equation in Fig.5 should have read,

$$te^{-t/CR} \longrightarrow \frac{1}{(s+1/CR)^2}$$

We apologize for this oversight.

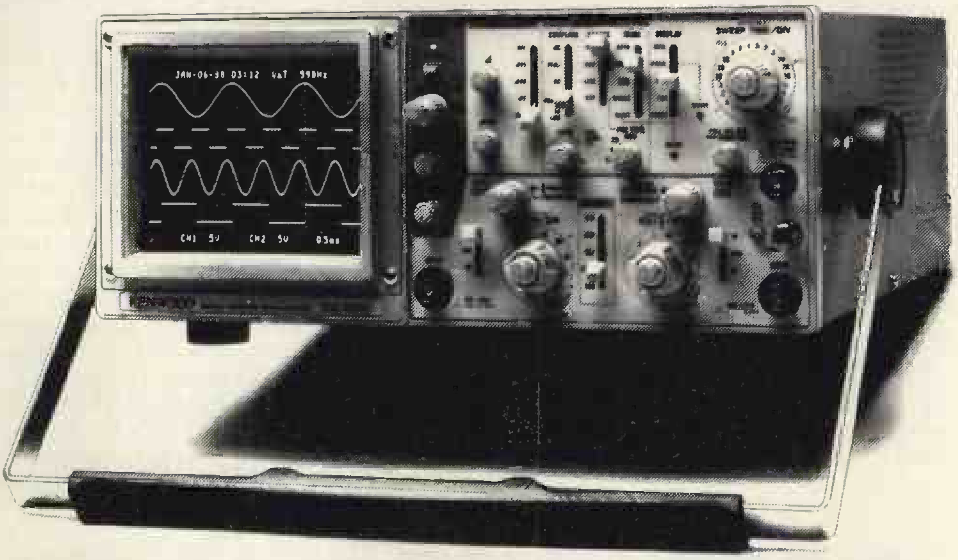
BOOKS

Programmer's guide to PC & PS/2 video systems by Richard Wilton. Nuts'n'bolts of EGA, CGA, MDA, VGA, Hercules and other graphics hardware for IBMs and clones: a mass of useful information for programmers and applications designers. Chapter headings include IBM video hardware and firmware, pixel programming, circles and ellipses, region fill, graphics text, bit blocks and animation, advanced video programming techniques. Appendices provide a summary of the video bios with details of system calls, a selection of screen-to-printer dump routines in assembly language and routines for identifying a computer's video hardware. The extensive program examples (mostly in assembly language or C) are reproduced in an artistic but somewhat faint shade of green. For those with poor eyesight, a disc is available from the US for \$24.95. The book, a 544-page large format paperback, is published by Microsoft Press, Penguin Books, at £22.95.

Marine electronic navigation by S.F. Appleyard with R. S. Linford and P. J. Yarwood. Second, enlarged edition, Routledge and Kegan Paul, £40. Textbook for those studying for navigating officer or radio officer qualifications. After covering the basic theory of radio propagation and time measurement, the authors deal in detail with all the principal radio navigation systems: Consol, Loran, Decca Navigator, Omega, Transit and Navstar-GPS. Further chapters cover sonar navigation, berthing systems, radar, marine communication systems and services, and the gyro-compass (this last is drawn from 'The Ship's Compass', by G.A.A. Grant and the late J. Klinkert). Clear and readable. Hard covers, 605 pages.

Electronic circuits handbook by Michael Tooley. Heinemann, £14.95. Cookbook for the student or technician, containing hundreds of circuits with associated design information. Categories include power supplies, amplifiers, logic circuits, timers and computer interfacing. Supporting chapters cover the practical side of choosing and using components, circuit construction and test equipment. Soft covers. 277 pages.

Practical digital electronics handbook by Mike Tooley. PC Publishing, £6.95. Introduction to the subject for newcomers: logic gates, monostables and bistables, timers, microprocessors, memories, i/o devices, interfaces, STE bus. Appendices include some constructional designs for digital testgear (logic tracer, RS-232 breakout box, counter/d.f.m. etc.). soft covers, 197 pages. PC Publishing is at 22 Clifton Road, London N3 2AR.

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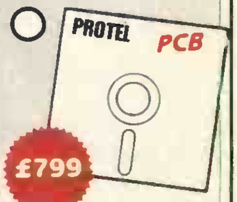
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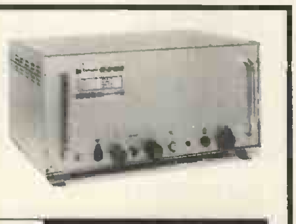

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ELECTRONICS & WIRELESS WORLD

INDUSTRY INSIGHT

COMMUNICATIONS

APRIL ISSUE

The second in the series is concerned with the explosively developing field of electronic communication of voice and data, using radio or cable techniques.

We look at private mobile radio, local area networks and the facilities offered by video services such as Prestel.

The way ahead in p.m.r. is not always clear, in view of political and spectrum considerations: industry experts present their views.

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RADIO COMMUNICATIONS

Tighter e.m.c. regulations

Draft proposals from the Commission of the European Communities for a Council Directive on "the approximation of the Laws of Member States relating to electromagnetic compatibility" (COM(87) 527 final, of November 1987) foreshadow major changes in UK legislation on electrical interference, including changes to the Wireless Telegraphy Act 1949.

Electromagnetic compatibility (e.m.c.) is defined as "the ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment". The DTI has circulated for comment copies of the 28-page draft directive, making clear its own reservations on some aspects of its implications for the industry, noting that the proposals cover all electric and electronic appliances, equipment and installations (except motor vehicles and tractors), and the whole of the electromagnetic spectrum.

The list of present and proposed European standards to which manufacturers will be expected to comply comprises radiation from television receivers and related apparatus; immunity of television receivers and related apparatus; radiation from information technology apparatus (BS:6527); radiation from industrial, scientific and medical apparatus; radiation from household appliances, portable tools, etc.(BS:800); and radiation from fluorescent luminaires (BS:5394).

While the standards with BS numbers have already been agreed, some amendments are currently in progress. The Commission has insisted that those marketing a product must certify that it meets the directive's objectives, although the DTI earlier considered this an undue burden.

The directive requires manufacturers to certify compliance except in the case of some telecommunications apparatus for which type-approval is envisaged. The DTI believes that the UK implementation of the proposals will require substantial changes to Part II of the Wireless Telegraphy Act 1949.

The DTI advises trade associations and companies with serious concern about the proposals not to lose any opportunity to lobby the Commission, possibly in association with their European counterparts, adding: "It should also be noted that after the Council of Ministers has adopted an initial position, the proposals will go to the European Parliament and Economic and Social Committee, so there are lobbying opportunities there too."

Such advice seems to indicate that DTI is more concerned with the impact of the directive on industry than with maximizing the reduction of spectrum pollution and minimizing e.m.c. problems. Meanwhile the amount of radiation from digital devices such as home and personal computers continues to represent a serious source of interference to television and broadcast reception and to all weak-signal reception, with BS:6527 in limbo.

Short-range meteor-scatter

Use of the short-lived but highly ionized trails left by meteors entering the earth's upper atmosphere to provide two-way communications in discontinous bursts has been recognized for more than 30 years and used primarily for defence communications, but also increasingly in this decade for civil applications. Most of the many millions of meteors daily entering the atmosphere produce trails with useful lifetimes of on average only about a quarter of a second, although a few, particularly during the regular meteor-shower periods, persist for many seconds.

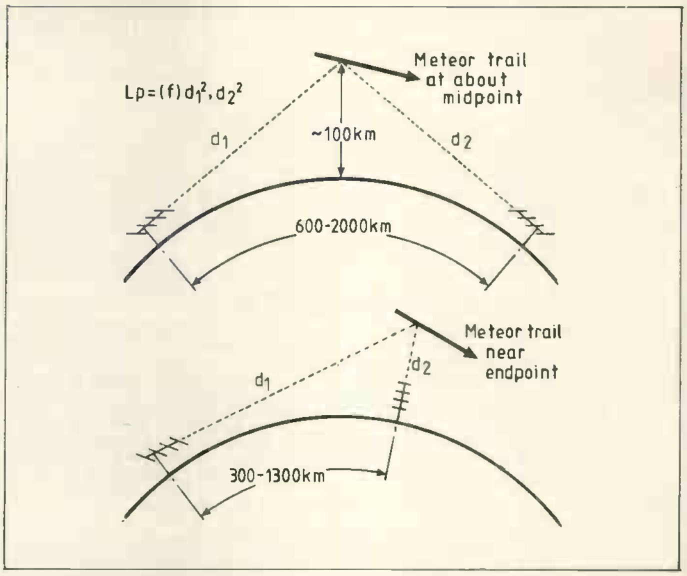
The trails provide reflective and scattering layers in the E region about 90 to 110km above the earth. Most meteor-scatter systems operate in frequency bands of about 30 to 50MHz or above, with an optimum range of between 800 and 2000km. Modern computer-controlled systems, with burst rates of the order of 4800 bit/s, can provide an average throughput roughly equivalent to a continuous radio-teleprinter link. Typically, transmitters of up to 1kW output are used with Yagi antennas with about five elements directed towards the E-layer midway between the terminals.

Radio amateurs have used this technique on 50, 70 and 144MHz for many years, though often concentrating only on the longer lasting trails. Chris Bartram, G4DGU, drew attention to a little-known method of reducing path loss over ranges of about 300 to 1300km. This is to orientate antennas to use meteor trails nearly overhead one station, rather than aiming at trails roughly mid-way between the two stations (*Radio Communication*, "Technical Topics" October 1981). He pointed out that not only can this result in a useful 8.3dB reduction of path loss at 1000km but also that other advantages arise: the high upward angle of one of the antennas means that its height above ground is of little or no consequence.

Many observations of meteor-scatter signals had convinced Chris Bartram of the value of overhead reflections though he had found it difficult to convince other enthusiasts.

Meteor burst is today acknowledged to be a useful and practical technique for reliable low data rate communication at ranges from 800 to 1200km. However, as Dr Jay Weitzen (Signatron Inc. and University of Lowell, Massachusetts) has pointed out in *IEEE Transactions on Communications*, (November 1987) there is still much controversy as to the usefulness of meteor burst as the range decreases below about 400km. He states that several experiments have shown that connectivity can be maintained at shorter ranges if the antenna patterns are designed properly. He puts forward three requirements that need to be satisfied. These bear out and also extend the 1981 observations of Chris Bartram.

Dr Weitzen concludes that for shorter ranges the antenna patterns at both terminals must be designed to illuminate not only the regions between the stations, but also the regions above and to the rear of the stations: at short ranges a significant portion of the duty cycle, he finds, is contained in these regions. Additionally, at short ranges, minimizing the synchronization and acquisition time is very important, much more so than at long ranges. Finally, increasing the burst data rate up to the point that the ratio of the packet duration to average burst duration is of the order of 0.5*a* (*a* being between 1 and 2) increases the actual throughput while minimizing the time to deliver a message.



Path loss of meteor-scatter signals can be reduced by the use of endpoint reflection. Aiming the antennas at trails directly above one station can give an improvement of some 8dB over a 1000km path.

Radio Communications is written by Pat Hawker.

Looking at the weather from space

Microwave and laser applications are to be studied for possible use in new ESA weather satellites. British Aerospace has been commissioned to investigate the feasibility of a microwave sounder which will measure temperature and water vapour content of the atmosphere at different levels. Such an instrument would have the advantage over infra-red and visible imaging instruments as it would be unaffected by cloud cover.

Wind is the main concern of the study to be undertaken by Ferranti, who will develop a high-powered CO_2 laser for possible use as a wind sensor. A lidar (light detection and ranging) uses the laser as a transmitter in a system that accurately measures the movement of air particles. Lidars have been used to demonstrate the detection of wind shear, a localized down draught which can affect the airspeed of an aircraft during take-off or landing.

Laser pulses are reflected by aerosol particles and movement is detected by measuring the Doppler-shift of the reflected light. CISE of Milan are handling the resonator design and frequency stability aspects of the laser cavity. Dornier of Germany is looking at the space qualification of the overall system. RSRE Malvern will be contributing its expertise in CO_2 laser technology.

Faster chips need not be smaller

The quest for larger-scale integration and higher speed has resulted in a rush for smaller geometries in integrated circuits; thinner conductors placed closer together and smaller components. An alternative has been found by Linear Integrated Systems, who have developed a four-layer interconnect c-mos process that achieves toggling speeds of 300MHz and higher circuit densities.

Four layers of interconnection are achieved without adding to the complexity of the circuits and can be produced at lower cost than conventional c-mos i.cs. The use of sputtered refractory metal interconnection increases speed over silicon-gate devices by a factor of up to ten times. Speed can be further increased by using molybdenum rather than aluminium.

Radiation hardness has been developed by using gallium and arsenic as silicon dopants without the cost overheads of full GaAs devices. Another advantage is that sputtered layers can be buried within the silicon and surface interconnections no longer need to be arranged in channels.

The company has been responsible for many innovations. It designed the world's first quartz-controlled watch for Seiko. The development of on-chip thin-film resistors led to a number of linear devices, including the first single-chip d-to-a converter. Other 'firsts' were a heart pacemaker chip, a digital pocket pager i.c. and the development and production of the fastest flash a-to-d converter. The company now concentrates on standard linear products, second-sourcing many Harris devices, and on custom i.cs. The Californian company is represented in the UK by Tekelec Components.

Ultra-high-speed gate array

Pilot production has commenced on a Plessey gate array made in the 1μm bipolar process, developed as part of the Alvey programme (see the report on Alvey, p.1140 in our November 1987 edition.) Each of the 240 gates in the array can be configured in high, medium or low-power options with, respectively, 3.5GHz, 2.5GHz and 1.5GHz operation and gate delays of 80, 120 and 200ps.

The high speed has been achieved through such features as trench isolation, double overlapping polysilicon and three layers of metal interconnect. Three power options allow the user to choose the optimum speed/power combination for a particular application. Digital microwave and other high-speed communications are obvious candidates.

Electronics traders trade electronically

'Paperless trading for the electronics industry' was the title of a conference held recently in London where component manufacturers and distributors were told how the Tradinet Electronic Data Interchange (EDI) system has dramatically cut costs within the industry. Mike Pickett of Mullard, chairman of the AFDEC/ECIF working party on EDI pointed out that the cost of 1000 documents, including mail handling, computer cost, entry, verification and error correction amounted to £1510, which fell to £325 using the electronic network.

UK sales manager of Texas Instruments, Tony Wildman, stressed the saving in time, cutting the turn-around from received order to committed delivery date from five days to one.

Purchase orders were the chief concern of Keith Pierson of STC Electronic Services. The system had been so successful that his company was transferring other documents to the electronic medium.

Linking the system with parts, materials and engineering databases had been the main advantage to STC Telecommunications, said director Peter Gershon, who exhorted trading partners to set up "intravenous links between internal networks to achieve a maximum matching of blood groups."

Amphenol was so convinced by the arguments that it signed a contract with International Data Services, operators of the system, at the conference.

Arthur C. Clarke at 70

At 70, Arthur C. Clarke is still fully occupied with four novels, has planned a number of other books and at least two film scripts. Since 1956 he has lived in Sri Lanka, and is Chancellor of Moratuwa University, on the board of the Institute of Fundamental Studies and has a Centre for Modern Technologies named after him.

An accident in 1962 totally paralyzed him for a while and he still needs physiotherapy or other exercise, and to keep his public engagements to a minimum. Luckily the Sri Lankan institutions with which he is connected are all within six miles (10km) of his home in Colombo. One trip planned is to witness the total eclipse of the Sun from the Cunard luxury liner QE2 on March 18th, somewhere in the China Sea.

Clarke was awarded the Stuart Ballantine gold medal by the Franklin Institute in 1962 for his conception of the geosynchronous communications satellite, published in *Wireless World* in 1945. He now takes advantage of such satellites to transmit his texts to publishers and film producers.

Sarong-clad Arthur C. Clarke with his pet monkey and a British-built hovercraft used by his company, Underwater Safaris, for diving expeditions off Sri Lanka.

UPDATE

Broadcasting show in Spain

Munditele is the name of a new broadcasting show to be held on 15 to 19 April in Zaragoza, North-east Spain, in new exhibition grounds opened last year by the King and Queen of Spain.

A Festival of Television will include the Caesar Augustus awards for the best drama series on tv. Z awards will go to people for outstanding tv work. There will also be a general market place for tv productions. This will be complemented by a radio and tv equipment trade show and a series of conferences and symposia on all aspects of broadcasting.

European plans for h.d.tv

The aim of the Eureka high-definition tv project, which involves some 30 European broadcasters, research institutes and industrial companies, is to define a standard for a system compatible with the MAC transmission system for satellite broadcasting. A complete prototype production and transmission system is planned to be developed and demonstrated by 1990.

The BBC is to contribute its knowledge of digitally-assisted tv. The MAC system was developed by the IBA and both authorities will have financial backing from the DTI for their participation in the project. Preview demonstrations are planned to take place at the International Broadcasting Convention in Brighton in September.

Opponents of relativity unite!

Concepts of space, time and energy are to be aired at an International Congress on relativity and gravitation which aims to unite all scientists who do not accept Einstein's theories.

Offering experimental evidence, the organizers claim that: "kinematic and gravitational acceleration are two different categories and there is no equivalence between them". If correct, there would need to be a massive re-think of many basic and cosmological concepts: the big-bang hypothesis would be wrong; the Hubble shift would be caused by cosmic gravitational shift; the universe would be infinite and the velocities of celestial bodies would be very low.

Special homage will be paid to the memory of Nikola Tesla: "the eccentric solitary genius who helped lay the experimental fundamentals of our electromagnetic civilization and who unlocked many doors to the secrets of nature. One must be justifiably indignant that the name of Einstein, who brought physics to a terrible mess, is known to every child, while the name of Tesla is ignored, even by the physicists."

The Congress takes place in Munich, 22 to 24th April and is organised by Emil A. Maco, Gesellschaft zur Förderung der Randwissenschaften, Georgiestrasse 31, D-3000 Hanover, West Germany. Tel: (0511) 326251.

Multilayer ceramic substrates

With integrated circuits becoming bigger and faster there is a greater need for advanced interconnection external to the devices which is also densely packed and which does not degrade performance, especially speed.

ERA Technology are undertaking a study of multilayered ceramic materials. The 'buried metal' technique, tracks of conductor between ceramic layers, seems to offer a promising approach but the process is highly complex and needs very careful control. Ceramic materials which need much lower temperatures for firing are a possibility and some companies have adopted this method for internal use. Similar materials are now becoming commercially available. One such uses a filled glass ceramic which has the same coefficient of expansion as alumina and may be fired at about 850°C, allowing conventional thick-film conductors to be used. The ceramic is sold in an unfired 'green' state and can be printed with conductors and resistors before firing.

Although there seem to be considerable advantages in the materials there are still areas that require further investigation: the handling and assembly of fragile substrates; the cutting of through holes for connection between layers; and the design limitations imposed by shrinkage during firing.

ERA is proposing to undertake the research on behalf of a number of clients who will share the costs and will be able to have circuits of their own design made for evaluation.

John Bowers

John Bowers, founder and chairman of Bowers and Wilkins, died on the 20th December, aged 65.

With Roy Wilkins, with whom he served in the army, he started a radio and hi-fi shop in Worthing. His own love of music led to his experiments in loudspeaker design and with Peter Hayward he founded B&W Loudspeakers in 1966. He claimed a number of achievements, including the first linear-phase loudspeaker, the use of laser interferometry in audio technology and digital techniques in quality control. Conscious of the need for styling and design, he worked in conjunction with Dr Kenneth Grange to create enclosure designs which complemented the technical excellence of the speakers. His greatest pride was in the company's acoustical research laboratory, claimed to be the best in Europe.

Report on interference

Electromagnetic interference is the subject of a wide-ranging report published by the Institution of Electrical Engineers. It summarizes the sources of e.m.i. from lightning to CB radio and points out the problems and methods of overcoming them.

Future trends are also dealt with. Potential sources of e.m.i. are growing more numerous with office IT systems and microprocessor-controlled equipment, together with cordless and mobile telephones.

Summaries of the main national and international recommendations and standards dealing with e.m.i. and electromagnetic compatibility are included.

The aim of the report is to generate a greater awareness of problems that may arise and to identify those areas where work needs to be done. Copies of the Report, 'Electromagnetic Interference' are available, price £10, from the IEE, PO Box 26, Hitchin, Herts SG5 1SA.

In brief

Cambridge University is to provide each of its 15,000 students and staff with a desk-top computer. The 5-year strategy, Project Granta, is expected to have 1000 devices in place by the end of the year, the majority being Acorn Archimedes models, which will also be used to replace the BBC micros at present in use. All the computers will be networked through optical-fibre links and will have access to mainframe and Unix-based minicomputers as well as a number of other facilities, including facsimile devices. Funding will be mainly provided by the departments and colleges of the university. Very much a local affair, the Cambridge equipment is being supplied by a Cambridge company, Qudos.

D-MAC/packet equipment for the IBA's d.b.s. uplink is to be supplied by EB Telecom of Norway. Similar coding equipment is already in use in Norway which may account for EB Telecom's success in landing the contract. Terrestrial test D-MAC signals, to commence in July to assist receiver manufacturers, are to be followed by test satellite signals. Delivery of the main equipment will be in Spring 1989 in preparation for the launch of the service, due in Autumn 1989.

BBC engineers have completed installing the RDS network for all the v.h.f. transmitters in England, ahead of schedule. They will now go on to the rest of the UK. Initial services will allow suitable receivers to tune automatically to the strongest signal, display the station name and the current time and date. Travel information allowing traffic information to be received automatically by mobile users is to be added in Autumn. The whole service will be officially launched at the BBC Radio Show, Earls Court, September 30 to October 10th.

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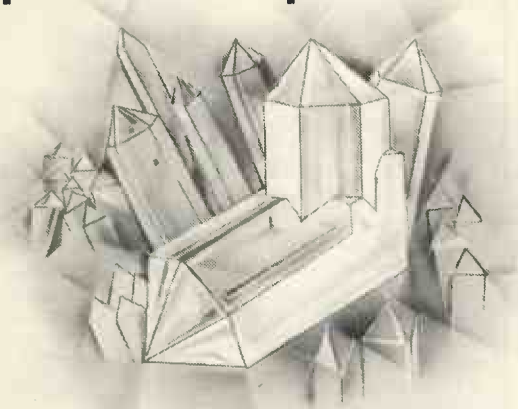

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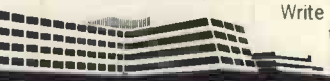

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Candidates may be expected to undergo a written test and interview.

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University of Surrey
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Volume 93

1987

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Regular columnists during 1987;
Pat Hawker (Radio Communications, Radio Broadcasting, Television Broadcasting)
Stephen Horn (Workfile)
Tom Ivall (Satellite Sytems)
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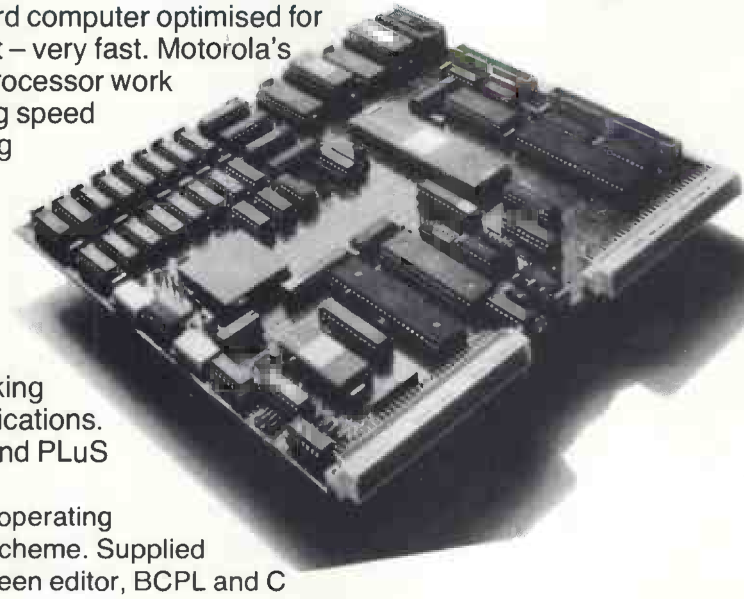

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