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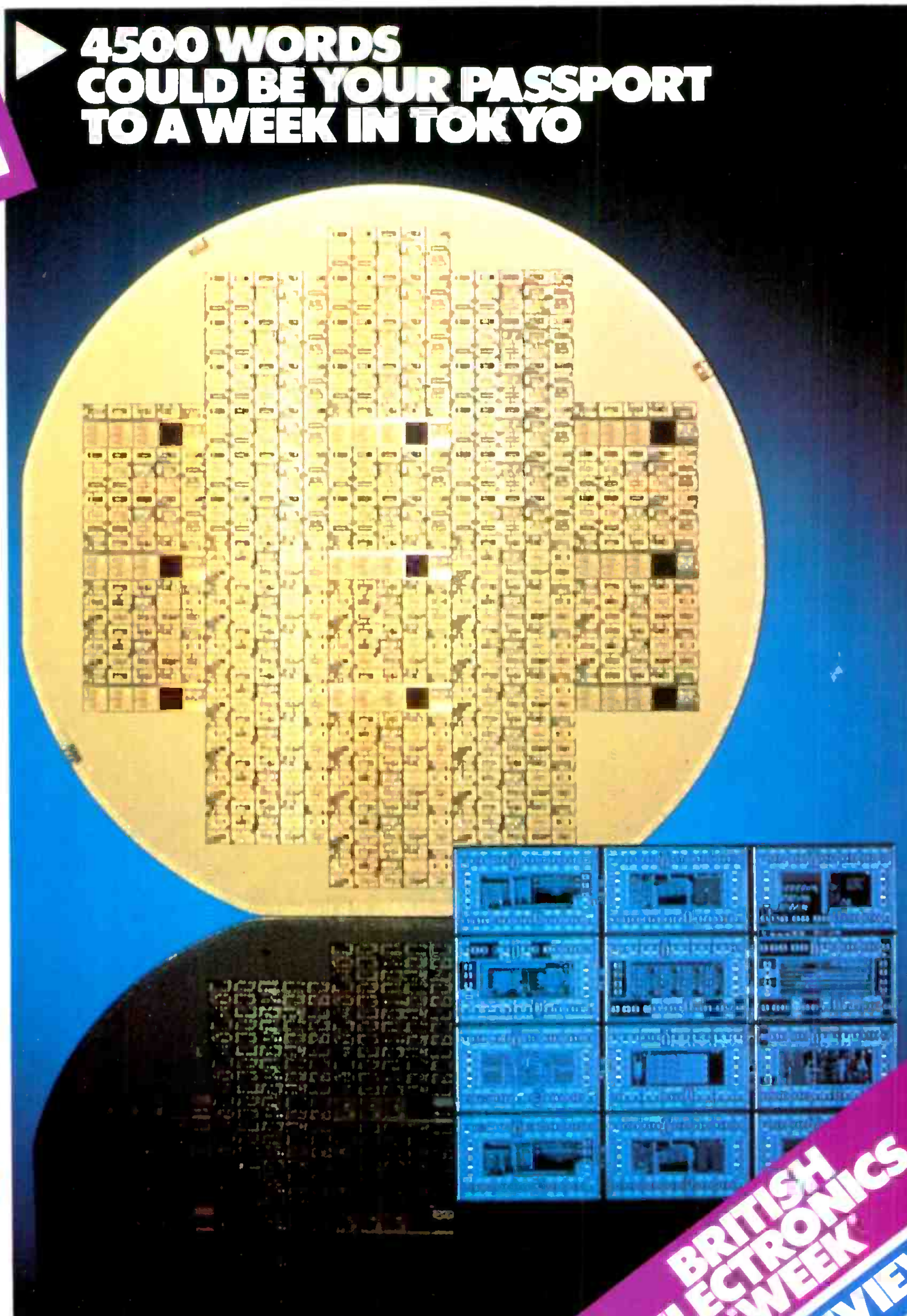

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CONTENTS

MAY 1988 VOLUME 94 NUMBER 1627

FEATURES

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Engineers and management

"We need to ensure that our best resources are used to achieve forward-looking leadership to meet future needs." So says the author of a report published by the Engineering Council, entitled 'Management and business skills for engineers'. The report maintains that British industry needs to put more effort into developing engineers and technicians into managers and goes on to remark that "we need to ask ourselves whether we are making the best use of the potential of these young people who train as engineers". It also attempts to explain why engineers can make good managers.

The report considers it significant that many of our industrial competitors abroad appear to have more companies led by chief executives with a technological background than we do in the UK. As a statistic that may or may not be relevant, but any attempt to show that a good engineer will automatically make a good manager must be viewed with a certain amount of suspicion. Industry is full of engineers who have been "promoted" beyond their competence, their exceptional talents having been submerged in the routine of general management. Fortunately, there are many who would resist any suggestion that they should forsake the discipline for which they were trained and do not see a mid-career diversion to financial and business affairs as a promotion.

However, companies are structured in such a way that a change of career towards management brings with it a substantial change in the potential rewards, reflecting the view that the technical and scientific staff of an engineering company are of less importance than those who deal with administration, finance, marketing and accountancy. To be fair, the author of the report does point out that some engineers wish to continue engineering and that some companies provide a path upwards for them, but the impression gained is that general management must be the goal.

In theory, the top management of a company involved with engineering should, of course, include engineers; they, after all, are uniquely qualified to direct the efforts of other engineers, to know what is possible and economically feasible and to oversee development. In practice though, such common sense does not prevail. An engineer who becomes a general manager effectively abandons his engineering skills and becomes indistinguishable from the accountants, economists and marketing people who concern themselves with "creating business performance... international diplomacy, politics, economics and finance". Since it is the best engineers who are rewarded with such promotion the result, all too often, is the loss of valuable engineering skills.

If the entrenched British view of company leadership could be changed to encompass the possibility of an engineer leading the company, being advised by the accountants *et al*, but concentrating on the engineering, something might be accomplished. But, although the report puts this point of view forward, it appears that ex-engineer company leaders would still be expected to concern themselves with affairs for which they are not trained and which can be handled more effectively by those who are.

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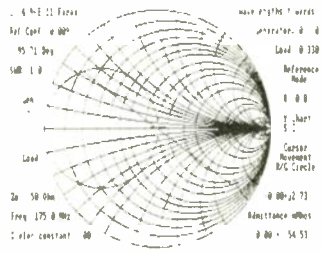

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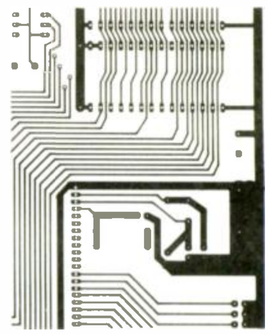

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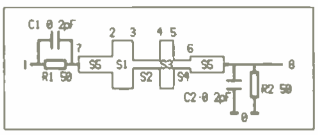

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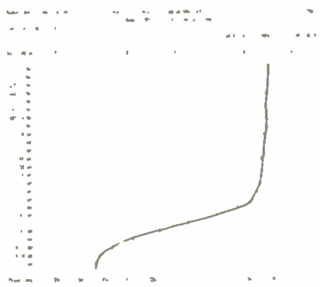

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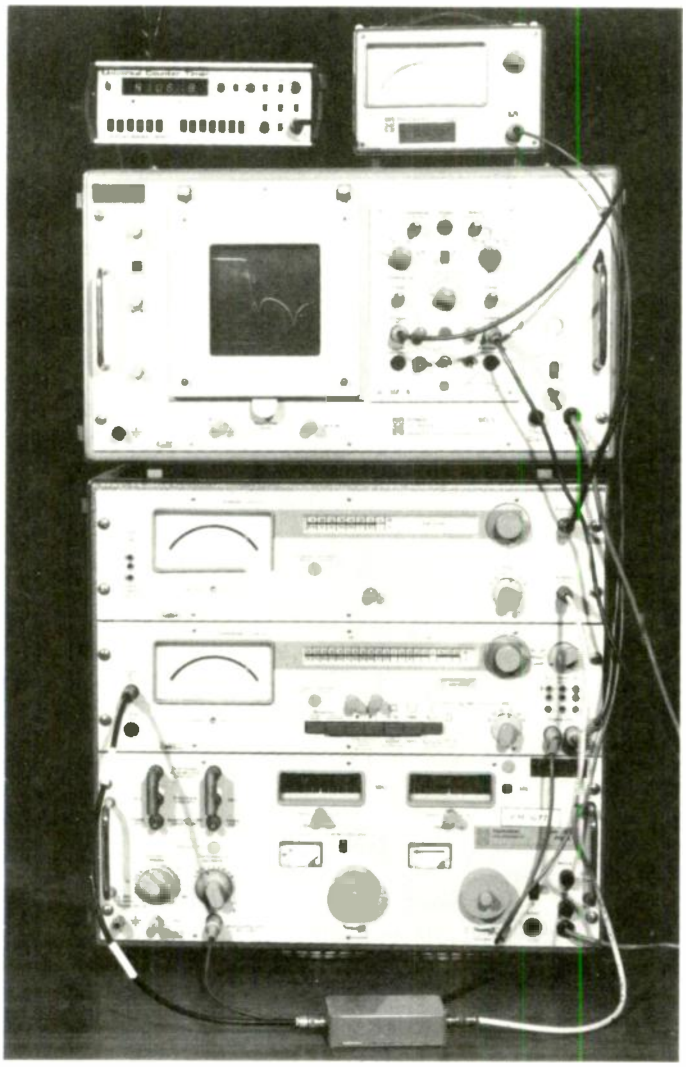
Sensitivity-based filter tuning

Sensitivity analysis has been used to tolerance computers at the design stage. This article shows that a computer will ease the consequent tuning process

BARRIE W. JERVIS and MILTON CROFTS



Test set used to obtain figures for attenuation versus frequency for input to the computer, running the Antreich algorithm.

Sensitivity analysis has been used for tolerancing components in electronic circuits such as filters.[1] In those applications, the objective is to determine the maximum tolerances the individual components may have to ensure that the filter performs to specification: large permissible tolerances mean that cheaper components can be employed. Then, during or at the end of the manufacturing process, the filter must be tuned to perform within specification, taking into account the effects of component errors and of stray capacitance or inductance. Tuning, which may be defined as bringing the performance within specification using the least number of steps, is frequently performed intuitively by skilled operators and may be a time-consuming and therefore costly business. It is desirable to offer computer-aided tuning both to assist the operators by eliminating boredom and fatigue, and to reduce costs.

Various approaches to the computer-aided tuning of both active and passive filters based on sensitivity analysis[2-6] have been described. In this article we focus on the tuning of the magnitude response of passive, seventh-order, elliptic LC filters using the tuning algorithm due to Antreich, Gleissner, and Muller.[2]

SENSITIVITY ANALYSIS

In sensitivity analysis, errors in component values are related to the errors in the circuit function of interest through a quantity known as the sensitivity[1,7-9]. The fractional change in magnitude response $\Delta F/F$, for example, is related to the fractional error in the component K causing it, $\Delta X_K/X_K$, by the expression

$$\frac{\Delta F}{F} = S^F_{X_K} \frac{\Delta X_K}{X_K} \qquad (1)$$

where $S^F_{X_K}$ is the sensitivity. However, the definition of the sensitivity[10] for large changes, ΔF, in F is

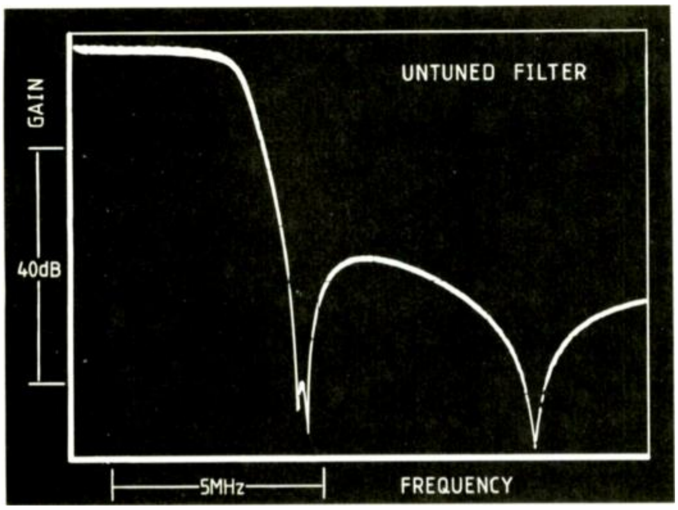
$$S^F_{X_K} = \frac{X_K}{F} \frac{\Delta F}{\Delta X_K} \qquad (2)$$

While equation (1) describes $\Delta F/F$ due to the Kth component, the effect of all component errors on $\Delta F/F$ can be found by summing over all K components, assuming linearity. Equation (2) shows how to calculate the large-scale sensitivity of the magnitude response due to an error in component K. At each frequency the nominal response is calculated for nominal component values, the latter then being incremented by ΔX_K and the changes ΔF computed. $S^F_{X_K}$ is then calculated. From equation (1) we can see that in principle for a real filter, if we know the nominal values, have calculated the sensitivity, and have determined ΔF experimentally, we can solve for the error ΔX_K in X_K, and hence make the appropriate adjustment, $-\Delta X_K$.

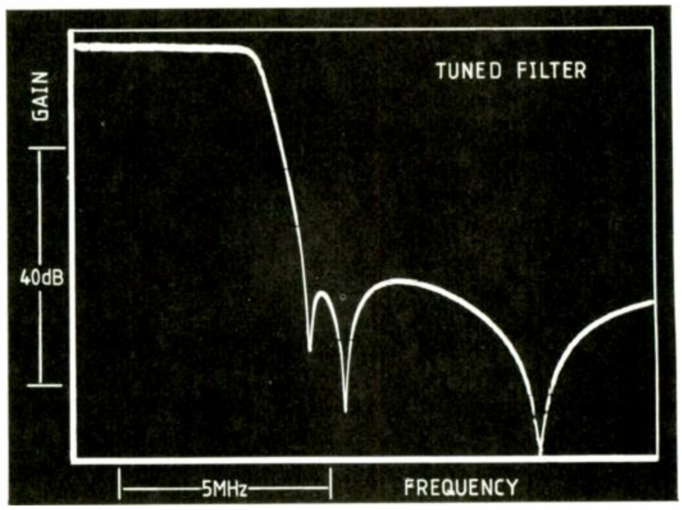
In practice, the procedure is somewhat more complicated, because the necessary adjustment to component K depends upon the sensitivities of the other components, and also the measurement frequencies need to be chosen with care. Furthermore, not all the filter components will be adjustable, and so those which are have to compensate for those which are not. It is also of interest to know which components are the more sensitive, because these will be the most usefully tunable, and which components interact strongly, i.e. which components have correlated sensitivities. For design purposes it is also useful to be able to estimate the permissible tolerances of the fixed components and the necessary ranges of adjustment of the adjustable components.

A sensitivity matrix[2], S, may be defined as

$$S = \begin{pmatrix} S_{11} & \cdots & S_{1r} \\ \vdots & & \vdots \\ \cdot & S_{ij} & \cdot \\ \vdots & & \vdots \\ S_{n1} & \cdots & S_{nr} \end{pmatrix} \qquad (3)$$



Response of the untuned filter.



Filter response after the tuning process.

where the S_{ji} are the sensitivities at the frequencies j of the ith components (n frequencies and r components in total).

Each column of **S** corresponds to the sensitivity vector $\mathbf{S}_i$ associated with a particular component at different frequencies. Pre-multiplication of **S** by its transpose yields the matrix $\mathbf{H} = \mathbf{S}^T\mathbf{S}$: the elements of the leading diagonal of **H** are then the squared magnitudes of the $\mathbf{S}_i$. Comparisons of the calculated $\mathbf{S}_i$ indicate the most sensitive components.

The interdependence matrix, the elements of which are $\cos a_{ix}^2$, where

$$\cos a_{ix} = \frac{\mathbf{S}_i \cdot \mathbf{S}_x}{|\mathbf{S}_i| \cdot |\mathbf{S}_x|} \qquad (4)$$

may also be calculated, using (4). a_{ix} is the angle between $\mathbf{S}_i$ and $\mathbf{S}_x$. When $\cos a_{ix} = 0$, the sensitivity vectors $\mathbf{S}_i$ and $\mathbf{S}_x$ are independent, whereas when $\cos a_{ix} = 1$, $\mathbf{S}_i$ and $\mathbf{S}_x$ are totally dependent, or correlated. Thus, sensitivity vectors which form large elements $\cos a_{ix}$, are the ones associated with strongly interacting components. If the normalized component error, $\Delta X_K/|X_K| = \Delta X_{KN}$, produces the normalized magnitude response error $\Delta \mathbf{F}_N = \Delta F/|F| = \epsilon$, and then ϵ is reduced by suitable tuning to a residual value ϵ_R, it can be shown that

$$(\mathbf{S}_b\mathbf{M})^{-1}.\epsilon_R = \Delta\mathbf{b} \qquad (5)$$

where $\mathbf{S}_b$ is that part of the partitioned sensitivity matrix **S** which represents the non-adjustable circuit elements;

$$\mathbf{M} = \mathbf{I} - \mathbf{S}_a\mathbf{S}_a^{+} \qquad (6)$$

where **I** is the identity matrix, $\mathbf{S}_a$ is that part of the partitioned sensitivity matrix which represents the adjustable circuit elements and

$$\mathbf{S}_a^{+} = (\mathbf{S}_a^T\mathbf{S}_a)^{-1}\mathbf{S}_a^T \qquad (7)$$

$\Delta\mathbf{b}$ represents the normalized deviation of the untunable component values from their nominal values and the maximum permissible residual errors, ϵ_r, are defined in the specification of the filter performance.

Thus equation (5) specifies the maximum permitted errors in the values of the fixed components, allowing specification of their tolerances. When $\Delta\mathbf{b}$ has been determined, equation (8) can be used to calculate the amount of adjustment to be provided in the adjustable components.

$$\Delta\mathbf{a} = -\mathbf{S}_a^{+}.\mathbf{S}_b.\Delta\mathbf{b} \qquad (8)$$

where $\Delta\mathbf{a}$ represents the amount of normalized adjustment to be accommodated. Thus the use of (5) and (8) greatly assists the practical design.

TUNING PRINCIPLES

It was indicated above that the filter has to be tuned to correct for errors in both the adjustable and the non-adjustable components. The principle adopted is to minimize the mean square residual error expected over the frequency range of interest. This averaging procedure is necessary to account for the frequency-dependent sensitivities of the different components over the frequency band. Thus the normalized correction vector is

$$\Delta\mathbf{x} = -\mathbf{S}_a^{+}.\epsilon \qquad (9)$$

The implications of equation (9) are seen if it is expanded for the case of adjusting two components at two frequencies when, for example,

$$\Delta x_1 = \frac{\epsilon_{\omega_1}}{S_{11} - \dfrac{S_{12}.S_{21}}{S_{22}}} + \frac{\epsilon_{\omega_2}}{S_{21} - \dfrac{S_{11}.S_{22}}{S_{12}}} \qquad (10)$$

where Δx_1 is the error in component 1; ϵ_{ω_1}, ϵ_{ω_2} are the measured errors at frequencies ω_1 and ω_2, and the S_{ji} are the sensitivities of the ith components at frequency ω_j. The adjustment to component 1 depends upon the errors and sensitivities at both measurement frequencies and upon the sensitivities of both components.

Equation (9) provides the basis of the tuning algorithm. $\Delta\mathbf{x}$ is computed knowing the calculated $\mathbf{S}_a^{+}$ and the measured magnitude response error, ϵ. The matrix $\Delta\mathbf{x}$ indicates the amount of adjustment to apply to each of the adjustable components. Thus, the principle is clear, but practical problems remain. It is necessary to decide how to calculate the sensitivity, at how many frequencies to make the calculations, and how to model the inductance, capacitance, or resistance changes in terms of the characteristics of the adjustable elements.

We have applied the method to passive, seventh-order, low-pass elliptic LC filters. Figure 1 shows the circuit diagram, and Fig. 2 shows a typical magnitude response. A characteristic feature of these filters is the attenuation poles in the stop band at the frequencies ω_2, ω_4 and ω_6, due to the resonances between the three inductors and their associated capacitors. These inductors are the only tunable components in the filter.

Measurement must be carried out at frequencies at which the sensitivities of the response to the different components are uncorrelated, so that the sensitivity is essentially attributable to just one component at the measurement frequency. The choice of measurement frequencies is influenced by the relationship between component and response variation which must be almost linear to allow the use of the large-scale sensitivity. Now the sensitivity of the magnitude response to a particular pole-producing component is very marked at the associated attenuation pole frequency (Fig. 3). However, these regions which satisfy the criteria for low correlation are regions of non-linearity between the response and compo-

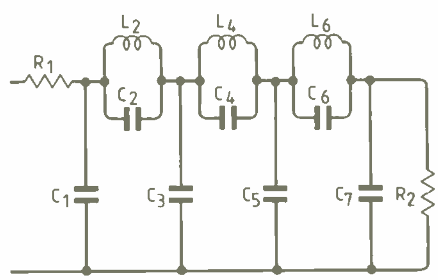


Fig.1. Circuit diagram or low-pass elliptic LC filter

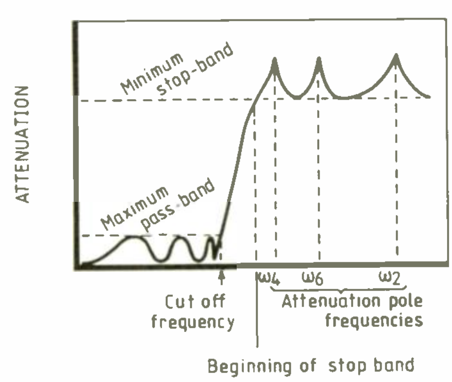


Fig.2. Magnitude-frequency response of elliptic filter shown in Fig.1

nent error, as in Fig. 4. It turns out that the use of pairs of test frequencies on either side of the poles provides sufficient measurement points, and offers a good compromise between the requirements of linearity and uncorrelated sensitivities. Since there were three poles, measurements were made at six test frequencies.

The procedure adopted was firstly to calculate the nominal response using the cad package ECAP on a mainframe computer. Then, the sensitivity analysis was carried out for the adjustable components at the measurement frequencies, so determining the matrix $\mathbf{S}_d$. This was done by perturbing each tunable component in turn from its nominal value by a selected percentage and computing the change in response, again using ECAP. Equation (2) then gave the corresponding large-change sensitivities. The response of the hardware filter was then measured and compared with the nominal response to obtain ϵ. The component errors were then calculated using equation (9) and converted to the required number of turns adjustment of the inductors. These adjustments were made and the response remeasured. If it failed to satisfy the specification, the new ϵ was calculated and the remaining procedure repeated. If the specification was met, the procedure was terminated.

PRACTICAL TUNING

Successful tuning requires a detailed knowledge of the features of the tunable components, here the inductors. The largest and smallest values of inductance of each of the inductors, and also the detailed shape of the inductance-turns characteristics are required.

Locations of the attenuation poles depend upon the inductance values; as the inductors are adjusted, the poles move along the frequency axis. The extent of this movement has to be known to ensure that the measurement frequencies are chosen to be always on opposite sides of their pole, and that the overlapping of adjacent poles is avoided by pre-tuning if necessary.

These precautions can be affected provided the range of the inductances, L, and their resonating capacitor values, C, are known, since the attenuation poles occur at the frequencies, f_p, given by

$$f_p = \frac{1}{2\pi\sqrt{LC}} \qquad (11)$$

The shape of the inductance-turns characteristic is needed in order to include a model of it in the tuning algorithm, so that $\Delta\mathbf{x}$ is output as the number of turns adjustment required: a typical characteristic is shown in Fig. 5. In practice, a highly accurate model is required for each inductor in order to achieve tuning within only a few iterations. Since such detailed modelling of individual inductors is not a practical proposition, an appropriate method is to use a linear model which demands some pre-tuning of the inductors so that they are operated only on a sufficiently linear portion of their characteristic. This is the procedure we adopted. The turns adjustment necessary to the ith component is given by

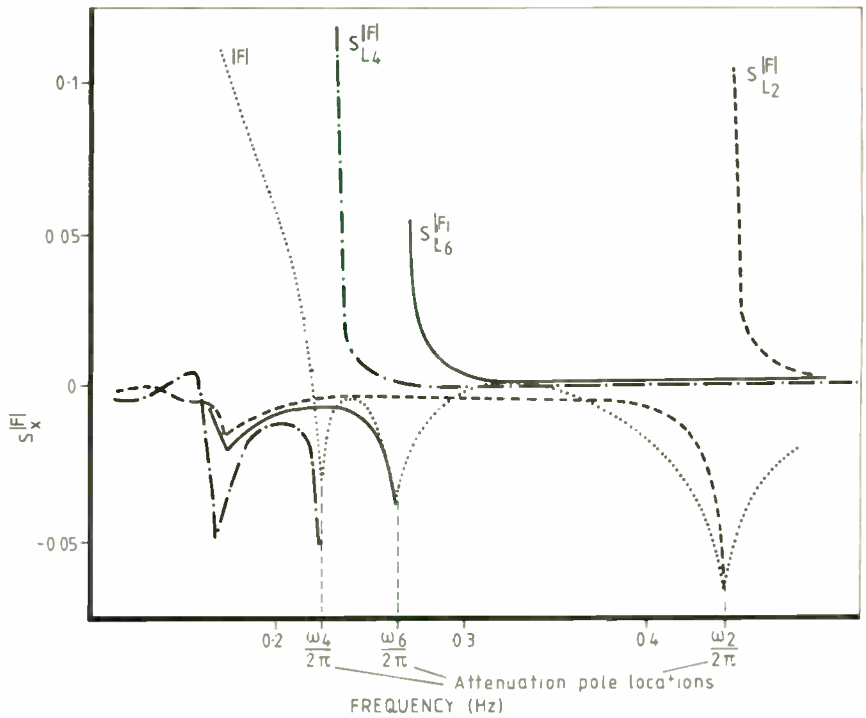


Fig.3. Magnitude sensitivity of elliptic filter versus frequency. Sensitivity peaks at attenuation pole frequencies

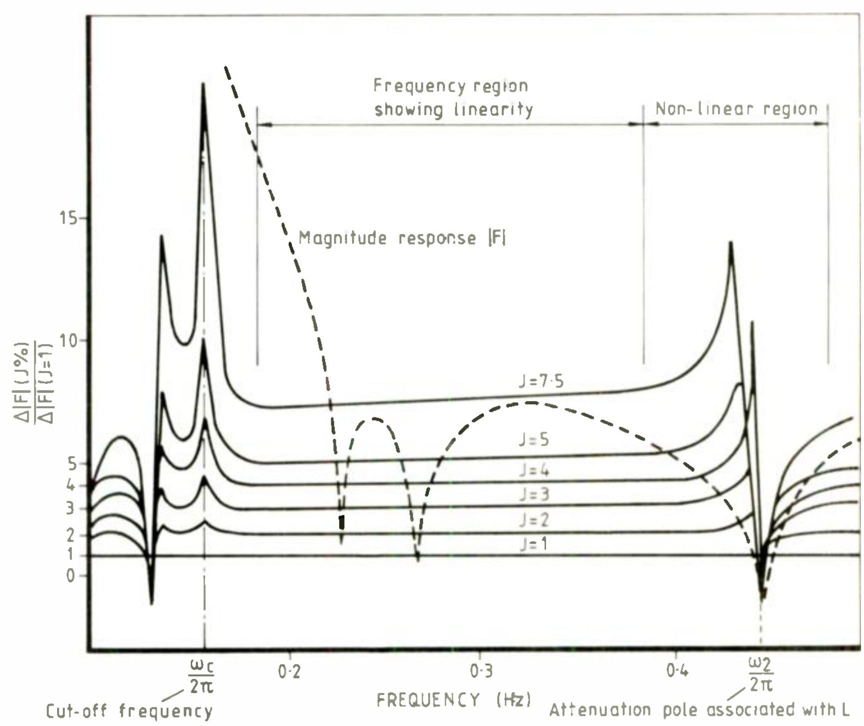


Fig.4. Magnitude response *versus* frequency with component errors as parameter

$$\text{turns}_i = \frac{\Delta x_i}{m} \qquad (12)$$

m being the slope of the inductance-turns characteristic measured about the value of the nominal inductance. The slopes of the three characteristics were found to be significantly different, being 0.31 and 0.38 and 0.10 μH/turn for L_2, L_4 and L_6 respectively.

EXPERIMENTAL MEASUREMENTS

The filter had a cut-off frequency of 4.51 MHz and the design specification is shown in Table 1. The inductors L_2, L_4 and L_6 were pre-tuned to within the linear portions of their respective inductance-turns characteristics and to within the restrictions imposed by pole movement. The magnitude response, which was the attenuation (dB)

Table 1. Design specification for the 4.51 MHz filter

Attenuation Pole frequency	Corresponding Components
6.039 MHz 7.033 MHz 11.595 MHz	L_6, C_6 L_4, C_4 L_2, C_2
Cut-off attenuation: −0.00348 dB at 4.51 MHz (passband ripple)	
minimum stopband attenuation: 45dB	

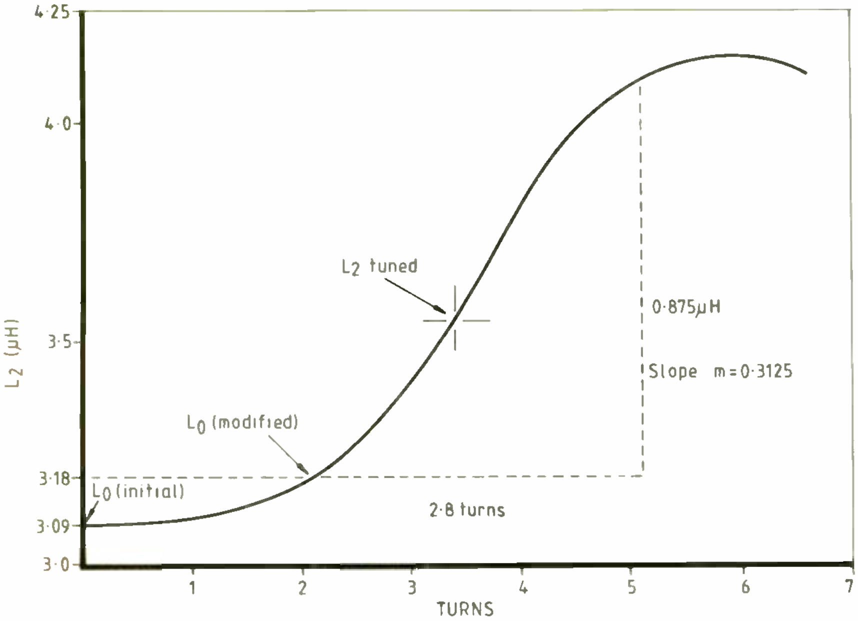


Fig.5. Inductance-turns characteristic of a tunable inductor

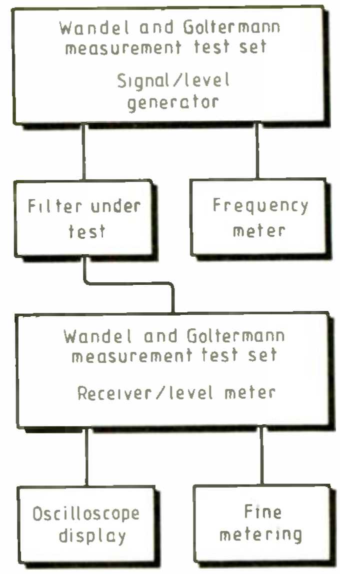


Fig.6. Measurement set-up using Wandel and Goltermann WM50.

Table 2. Sensitivities of the 4.51 MHz filter

Component	Sensitivity	Component	Sensitivity
L_2	16.3	C_2	± 16.7
L_4	15.4	C_4	± 15.2
L_6	14.9	C_6	± 14.6
C_1	− 0.76	C_3	· 1.5
C_5	− 1.16	C_7	· 0.30

versus frequency response, was measured using a Wandel and Goltermann test set with the filter inserted as the device under test (Fig. 6). The attenuation was measured at the six selected frequencies of 5.68, 6.39, 6.52, 7.32, 10.43 and 12.11 MHz. The attenuation values at each frequency were keyed into a program run on an IBM PC AT(E) microcomputer which implemented the Antreich *et al* algorithm[2]. The output was the number of turns adjustment required by the components.

RESULTS

Table 2 shows the largest sensitivities, S_i, found. This table clearly shows that the parallel resonant circuits, L_2C_2, L_4C_4, L_6C_6 are the most critical in the filter, since their components have by far the largest sensitivities. Table 3 shows the correlation coefficients, cos a_{ix}, of the sensitivities for various component pairs. The resonant circuit pair sensitivities (1-3) are highly dependent, which suggest that errors in the capacitors can be compensated by adjusting the inductors. Sensitivities of the capacitor pairs 4-8 are also highly dependent, the inference being that the component error of the more sensitive of the pair is the more critical: for example, C_3 is more critical than C_1. The dependencies of the sensitivities of all other pairs of components are much less.

Results of the tuning procedure are shown in Table 4, together with the designed-for response. Comparison of the responses before tuning, and after two or three iterations, with the designed-for response illustrate that the tuning procedure was effective, acceptable tuning being achieved after the second iteration. Finally, Table 5 shows the number of turns adjustment, the smallest

Table 3. Correlation coefficients of the sensivities of pairs of components of the 4.51 MHz filter

No.	Component Pair	cos a_{ix}	No	Component Pair	cos a_{ix}
1	L_2C_2	0.991	11	C_3C_4	0.157
2	L_4C_4	0.994	12	C_4C_5	0.147
3	L_6C_6	0.997	13	C_5C_6	−0.031
4	C_1C_3	0.878	14	C_6C_7	−0.188
5	C_5C_7	0.874	15	L_2L_4	0.043
6	C_3C_7	0.875	16	L_4L_6	−0.055
7	C_1C_5	0.893	17	L_2L_6	−0.005
8	C_1C_7	0.999	18	C_1L_2	0.145
9	C_1C_2	0.025	19	C_3L_2	0.183
10	C_2C_3	0.049	20	L_6C_7	−0.123

Table 4. Results of tuning the 4.51 MHz filter

Measurement frequencies (MHz)	Response (Attenuation in dB)				Designed-for response
	Before tuning	Number of Iterations			
		1	2	3	
5.68	27.24	35.18	33.17	33.55	33.31
6.39	57.27	48.86	50.72	50.56	51.23
6.52	55.09	50.22	51.73	51.54	52.23
7.32	61.62	59.79	59.53	59.49	58.54
10.43	58.42	58.62	59.02	59.01	58.63
12.11	70.46	69.32	68.49	68.49	67.18

Table 5. Number of turns adjustment per inductor required per iteration of the tuning algorithm.

Inductor	Before Tuning	Number of Iterations		
		1	2	3
L_2	0.1714	0.0945	0.0277	0.0267
L_4	0.0998	0.0778	0.0275	0.0266
L_6	1.4748	−0.3269	0.0721	0.0118

number being about 0.12 or 4.3° approximately.

References

1. R. Wheeler, Toleranced designs by computer circuit analysis, *Electronics and Wireless World*, December 1987, pp 1190-1192
2. K. Antreich, E. Gleissner, and G. Muller, Computer aided tuning of electrical circuits, *Nachrichtentechnische Zeitschrift*, vol. 28, Pt 6, 1975, pp 200-206
3. L.P. Lopresti, Optimum design of linear tuning algorithms, *IEEE Trans Circuits and Systems*, vol. CAS-24, No 3, March 1971, pp 144-51
4. J.F. Pinel, Computer-aided network tuning, *IEEE Trans Circuit Theory* vol.CT-18, January 1971, pp 192-4
5. R.L. Adams and V.K. Manaktala, An optimum algorithm suitable for computer assisted network tuning, *IEEE Proc. 1975 International Symposium on Circuits and Systems*, pp 210-212
6. T.D. Shockley and C.F. Morris, Computerised design and tuning of active filters, *IEEE Trans Circuit Theory*, vol.CT-20, July 1973, pp 438-441
7. H.W. Bode, Network analysis and feedback amplifier design, Van Nostrand, New York, 1945
8. S.J. Mason, Feedback theory – some properties of signal flow graphs, *Proc.IRE*, vol.41, September 1953, pp 1144-1156
9. J.Lidgey, Sensitivity analysis – what is it and what can it do? *Electronics and Wireless World*, May 1986, pp 46-47
10. Horowitz, Synthesis of feedback systems, Academic Press, New York, 1962

Barrie Jervis, B.A. (Hons., Cantab.), M.A. (Cantab.), Ph.D (Sheffield), M.I.E.E., is a principal lecturer in electrical and electronic engineering and Milton Crofts, B.Sc. (Hons), a research assistant at Sheffield City Polytechnic.

Multiple-spark ignition

Power mosfet switches make high-energy, multiple-spark ignition systems economical.

BRIAN TAYLOR

Ignition systems providing a multiple spark are not new, although for a variety of reasons, their implementation has been problematical. The main advantage of multiple-spark ignition systems over other ignition systems is that they ensure re-ignition of unburnt gases in the event of flame-loss. Among the benefits that can be derived from this are lower exhaust pollutant emissions, higher engine power, significant improvements in fuel consumption, and a reduction in the risk of pre-ignition.

Why, then, has multiple-spark ignition not been implemented before on a large scale? Early electronic ignition systems, sold as an add-on package to overcome the inherent weaknesses of the conventional Kettering-type distributor system, were of the capacitor-discharge variety. They were designed for use with the standard ignition coil fitted by the manufacturer.

The introduction of inductive-discharge systems required a change of ignition coil because of the lack of high-voltage power switching transistors at that time. It was not until high-voltage bipolar switching transistors were readily available that economically-priced inductive-discharge systems, using the standard ignition coil, became a reality.

The standard ignition coil exhibits a relatively large secondary capacitance which limits the generation of high-tension voltages with fast rise times.

Typically, a spark duration of 0.7 to 1.0ms would allow no more than about ten spark-cycles during the entire combustion phase. Furthermore, the magnetizing inductance of the coil prevents any appreciable current from flowing in the primary after the first spark has been generated, resulting in extremely weak subsequent sparks. In addition, the inherently poor switching performance of the ignition Darlington causes excessive dissipation resulting in poor overall efficiency and poor reliability. These problems must be overcome if an efficient, reliable multiple-spark ignition system is to be achieved.

MULTIPLE-SPARK GENERATORS

Since conventional ignition coil design is at the heart of these problems, its replacement by a high-efficiency ferrite-cored transformer is indicated. Replacing the flyback converter principle with a forward converter significantly reduces the number of turns required on the primary thereby increasing the turns ratio.

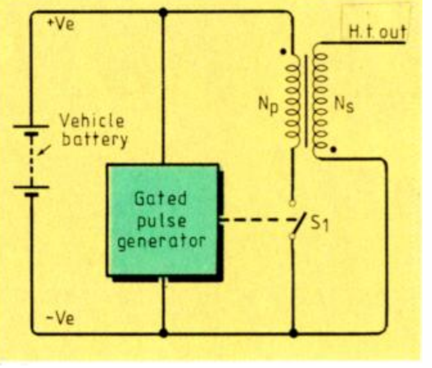


Fig. 1. Basic circuit of a multiple-spark ignition system.

Table 1 Comparison of power-mosfet and Darlington ignition systems.

Operating condition	Cranking	Running	
Battery voltage	6	14.5	V
Energy at spark plug during:			
2µs pulse	161.6	1039	µJ
fly-back	16.8	89	µJ
Total energy during 700µs spark	31	198	mJ
Comparative energy generated by a 1.4mH 10A coil using Darlington switch	10-15	70-100	mJ
Improvement in total available energy	107	98	%

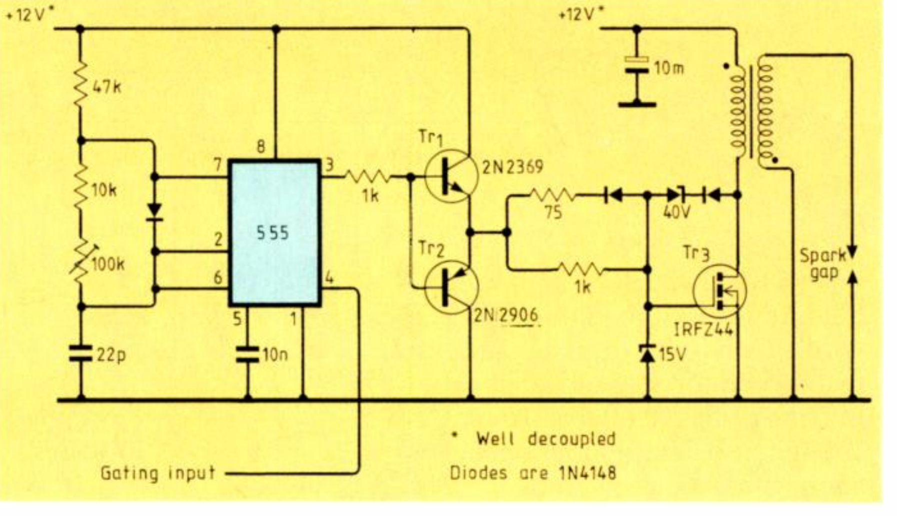


Fig. 2. In this design example of a multiple-spark ignition system, input gate pulses should be longer than 700µs if the total spark time requirement is to be met.

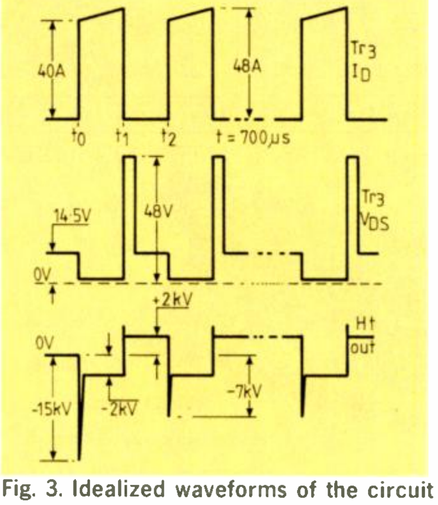
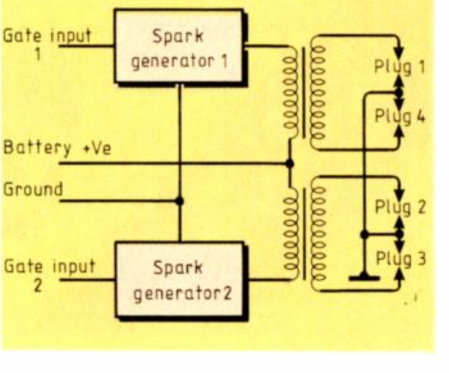


Fig. 3. Idealized waveforms of the circuit shown in Fig. 2. Time intervals t_0/t and t_1/t_2 are set to give 175 pulses within the 700µs spark-duration window.

Fig. 4. Secondary windings of this distributorless ignition system are floating so two plugs can be fired simultaneously.



In order to design a multiple-spark generator, Fig.1, two sets of operating conditions must be defined: those existing during cranking and those existing under normal running.

During cranking, the load imposed by the starter motor pulls the battery voltage down, so you can assume that under this load the battery voltage is 6V. Duration of each closure of S_1 is defined as t seconds, and the number of primary turns, N_p, is calculated as $N_p=6.t/(i_{mag}A_L)$ where i_{mag} is approximately 4A and A_L is the inductance factor of the core.

Using $E=L.di/dt$, set the current fall time through S_1 to give a maximum fly-back voltage of 50V across S_1. The number of secondary turns, N_s, is calculated to produce a peak aiming voltage of 50kV at flyback using $N_s=1000N_p$.

Peak aiming voltage is defined as the peak open-circuit voltage available at the high-tension terminal before the spark-plug gap breaks down. It should not be confused with the arc voltage present across the gap during breakdown. Aiming voltage should be as high as possible, within the insulating capabilities of the winding, in order to successfully 'fire' fouled plugs.

At the end of the first pulse of t seconds within the 0.7 to 1.0ms window the calculated 50kV peak aiming voltage appears at the h.t. terminal. In practice, this voltage will never be achieved since the mixture between the spark-gap electrodes will ionize, rapidly reducing the voltage across the gap to approximately 2kV. A demagnetizing current in the secondary winding due to the energy in the transformer $(L_{mag}.i_{mag}2/2)$ prevents immediate recombination of the ionized gas. The off-time of S_1 should be short enough to prevent full recombination.

At the start of the second and subsequent pulses, voltage at the h.t. terminal will try to reach $6.N_s/N_p$ but will be limited to the arc sustaining voltage of about 2kV. Arc current is limited only by the lumped resistance of the secondary circuit, resulting in a spark of sufficient intensity to ensure combustion.

For normal running, the ratio of N_s/N_p should be calculated to give $V_{BATT}.N_s/N_p=20kV$.

MULTIPLE-SPARK IGNITION DESIGN EXAMPLE

The circuit in Fig.2 is controlled by a gating input which should be longer than 700µs in duration in order to meet the total spark time requirement. The leading edge of the gating input must coincide with the ignition timing requirements.

In the idealized waveforms shown in Fig.3, the time intervals t_0/t, and t_1/t_2 are each set to approximately 2µs by the potentiometer, giving a total of 175 pulses within the 700µs spark duration window.

Table 1 shows performance figures taken from observed waveforms under both cranking and running conditions. Figures are also given for a Darlington ignition generator circuit for comparison purposes The Hexfet circuit shows an improvement of 107% under cranking conditions, where the available spark energy is of greatest importance. This improvement is a result of higher dissipation in the Hexfet, amounting to 8.56W compared to 5W in the Darlington. In real terms, the multi-spark generator exhibits an efficiency of 82% against 80% for the conventional system.

SCREENING

High levels of electromagnetic and r.f. interference, mainly around 250kHz and at frequencies up to 300Hz according to engine speed, are produced by the ignition unit. Precautions must therefore be taken to minimize interference. Radiated interference can be easily contained by housing the unit in a steel casing, while conducted interference can be controlled by passive LC filtering.

In a distributorless system, Fig.4, the unit can be mounted immediately above the spark plugs with the plug connectors as an integral part of the unit. The secondary windings are fully floating, enabling two plugs – one under compression and one at the end of the exhaust stroke – to be fired simultaneously by series connection. It may be necessary, in this configuration, to increase the N_s/N_p ratio to 1500:1.

It will be necessary to incorporate a charge-pump into the drive circuit for the Hexfet during the cranking operation.

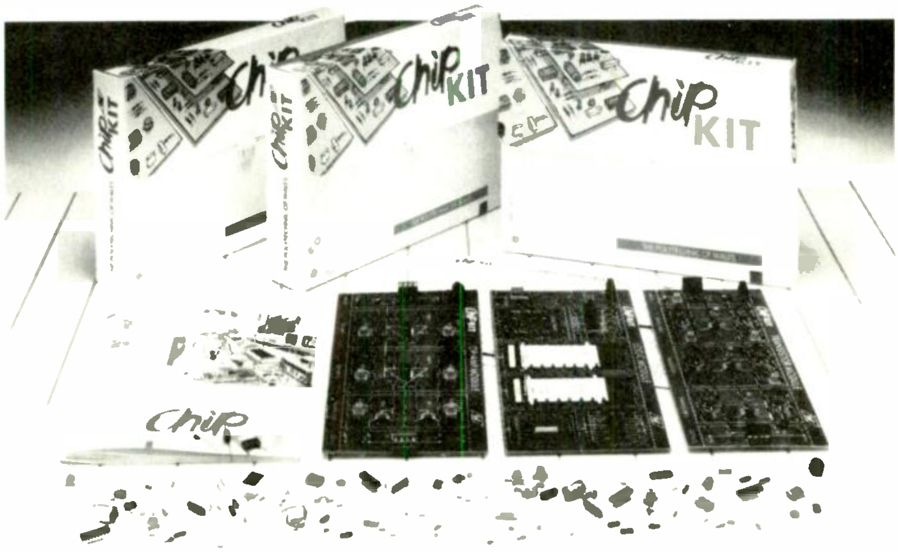
CONCLUSION

Practical high-energy multiple-spark ignition systems at a reasonable price are made possible by the introduction of mosfet switching devices such as the IRFZ44 Hexfet featured in this design. The benefits are both economical and ecological and I anticipate that such systems will be fitted to all new cars as standard equipment in the foreseeable future.

Brian Taylor is Business Development Manager with International Rectifier.

Low-cost teaching package

Chipkit is a do-it-yourself electronics teaching aid designed to enable even non-specialists to teach up to GCSE level. The packages, devised and produced by the Electronics Centre of the Polytechnic of Wales, aim to give pupils hands-on experience of the full range of electronic production techniques, and are suitable both for schools and for industrial trainees preparing for work on the shop floor.



Within the packages are circuit boards, components and a workbook featuring graded experiments, diagrams and questions for discussion. Besides seeking to make the subject fun, a major aim of Chipkit's design was to overcome the difficulty beginners often have in relating circuit diagrams to the physical component layout. Active and passive devices can be plugged directly into sockets on the boards for prototyping and can easily be removed for re-use.

Packages in the initial Chipkit range include a transistor module (at £32), giving a basic introduction to analogue circuit design and applications; an op-amp module; and a logic module (£37) containing t.t.l. gates, flip-flops, counters and a display driver. Also available are input and output boards containing switches, microphone, thermistor, l.d.r. speaker, relay and motor. All the classroom needs to provide is multimeter, oscilloscope and power supply.

Virtually all copyright restrictions on the printed material have been waived, enabling tutors to copy it for subsequent courses. But further copies, a component replenishment service and additional boards for soldering finished designs, are available from the Electronics Centre. As back-up, the Polytechnic will offer in-service training courses for teachers.

Details from Dr Richard Murray-Shelley at the Electronics Centre, The Polytechnic of Wales, Pontypridd, Mid-Glamorgan, CF37 1DL, telephone 0443-480480 ext. 2536.

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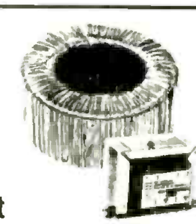

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Ampex's D2 video recorders

Technical outline of a controversial new digital video format

Readers who work outside the broadcasting industry may wonder that there is any need for yet another video recording format. Since 1956, when video recording emerged from the laboratory in the shape of the original Ampex quadruplex recorder, a succession of new formats (Table 1) has brought improved operating features and lower tape consumption. But recording technology and users' needs have continued to develop so rapidly that, for many purposes, today's conventional analogue machines are no longer considered to be adequate.

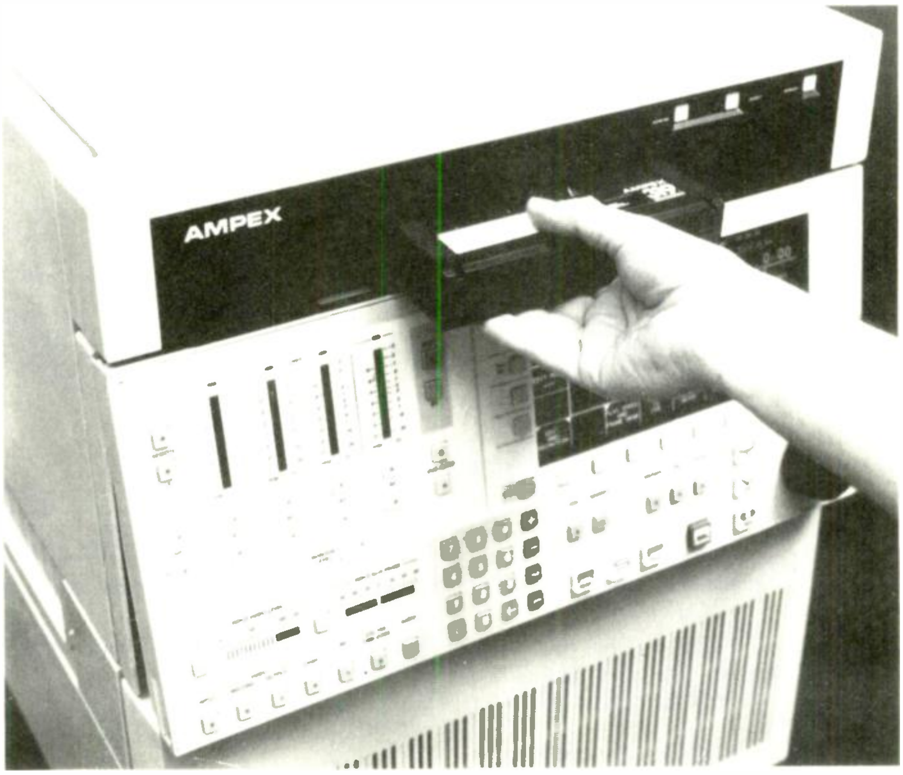
A digital replacement for these machines already exists, through the worldwide D1 format – a system based on 19mm cassettes, and one which carries the approval of both the EBU and the SMPTE. In the D1 format, the luminance and colour components of the vision signal are recorded on the tape separately. By combining digital quality together with freedom from crosstalk, this scheme greatly improves the clarity of the reproduced colour picture. Most significantly, it eliminates the objectionable 'cross-colour' patterning which is so characteristic a feature of composite in-band colour coding systems such as PAL.

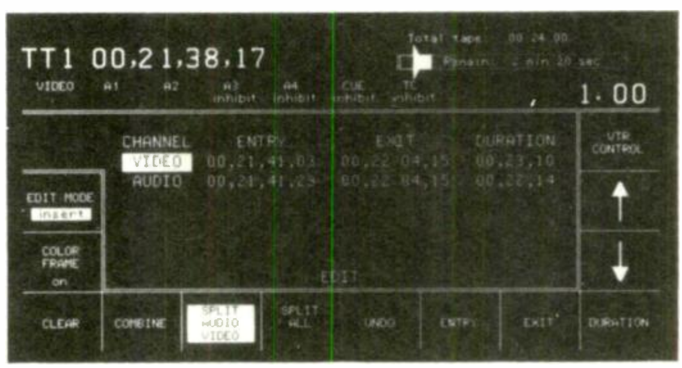
In the view of Ampex, however, D1 has a drawback which seriously restricts its usefulness. Virtually all the world's television studios still handle their vision signals in composite form – as NTSC, PAL or SECAM. To use D1, they must install analogue-to-digital and digital-to-analogue converters fore and aft of each machine. To take full advantage of D1, they must find the money to replace their entire studio system with new equipment which handles the signal in component form.

Whilst conceding that D1 is a well designed format, Ampex argues that it is ahead of its time, and that the need exists for a companion system based on recording the composite video signal. Ampex has now

Table 1: brief history of broadcast v.t.r. formats. A wag at Ampex extrapolates from these figures to show that by the end of the century the average video format will last 20 minutes, or less than the playing time of the tape. Shall we see the emergence of an adaptive v.t.r. which changes format whilst it records?

	Studio	ENG/EFP
1956	Quadruplex	
1969		¾ inch
1977	Type C, Type B	
1982		Betacam; Type M
1987	D1	Betacam SP; MII
1988	D2	





Top: loading a cassette into Ampex's VPR-300 composite-format digital video recorder. Controls on the left are for the four digital audio channels. Behind the operator's hand is an electroluminescent panel which displays time code, machine status and diagnostic information. Lower picture shows a typical edit-mode display.

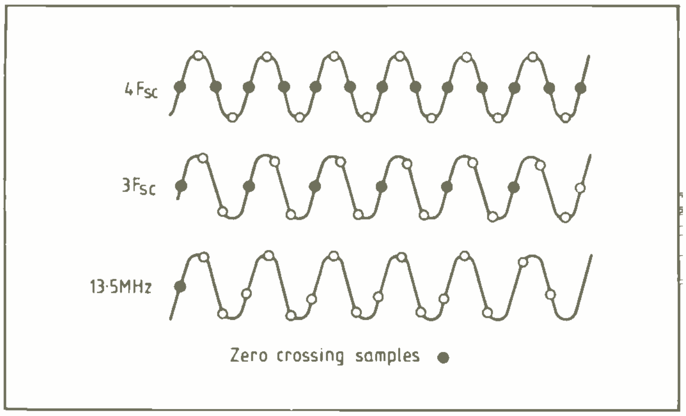


Fig.1. Sampling at $4f_{sc}$ provides twice as many samples at the zero-crossing point (the most sensitive region) as does $3f_{sc}$. The improved accuracy helps make possible such features as variable-speed playback.

Table 3: Characteristics of the PAL D-2 composite digital recording format.

Video sampling Quantization Tv lines recorded	$4f_{sc}$ – (17.7MHz) 8 bit 608	6.0MHz bandwidth 56dB signal-to-noise
Digital audio Audio sampling	4 channels 48kHz	20kHz bandwidth >90 dB dynamic range.
Medium Playing time	SMPTE 19mm standard 1.5kOe metal particle 32, 94 or 208 minutes	
Tape speed Longitudinal tracks	131.7mm/s Cue audio; control track (field, frame and colour frame); time code	

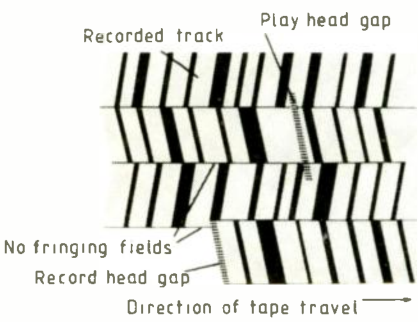


Fig.2. Azimuth recording, with a d.c.-free digital coding scheme. Eliminating the need for a guard-lane between tracks saves tape.

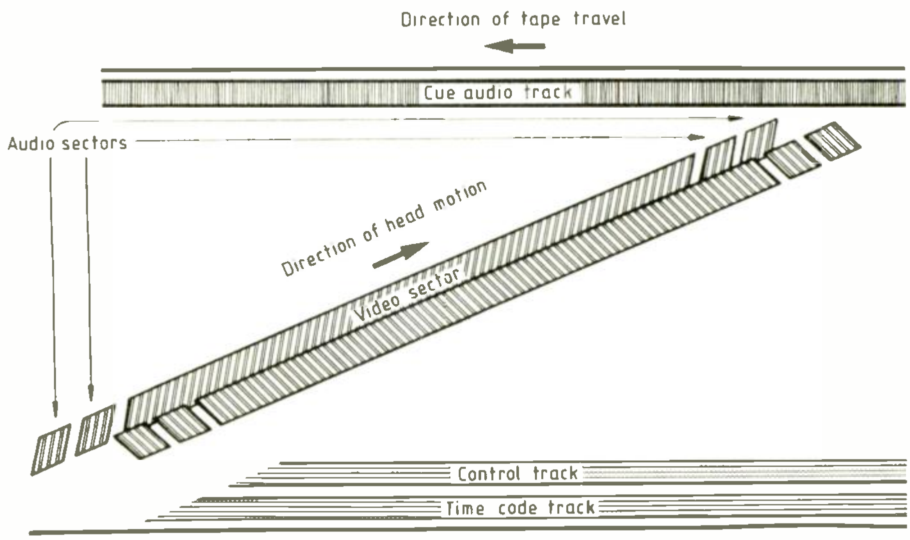


Fig.3. D2 format: how the recorded tracks are arranged on the tape.

announced such a system – which it calls D2 – and the company intends to launch D2 machines for the PAL system at IBC later this year.

One of the driving forces behind D2 was Ampex's need to find a replacement for its quadruplex machines, still widely used for playing out advertising spots at commercial stations. Preparing commercials often involves a great deal of multi-generation copying and so the benefits of a digital system, which would allow cloning, were highly attractive. To advertisers, good video quality is of the utmost importance.

Like D1, D2 is a cassette format – and indeed the cassette shells it uses are just the same, though the tape inside is different.

CHANNEL CODE

Perhaps the most fundamental decision in designing a digital video format is to pick a sampling frequency. Of the various options suitable for recording the 5.5MHz PAL signal (Table 2), Ampex has chosen the hardest: four times the colour subcarrier frequency ($4f_{sc}$, 17.7MHz). This means an enormous amount of data for the tape to carry (154Mbit/s in all), but it allows greatly enhanced reproduction of the colour subcarrier itself (Fig.1). In particular, it enables the eight-field PAL subcarrier sequence to be reconstructed accurately enough for good variable-speed playback – a feature very useful in the editing suite. Colour pictures are said to be recoverable at up to 60 times

Table 2: how video sampling rate affects the data storage requirement.

	Video bit rate Mbit/s	Tape bit rates Mbit/s	Packing density kbit/mm^2
$3f_{sc}$	106	116	54
13.5MHz	108	118	55
$4f_{sc}$	142	154	72

normal playing speed.

With so much data to record, minimizing tape consumption became a priority. Ampex engineers have tackled the problem partly through switching to a metal-particle tape formulation and partly through their method of coding the signal. By adopting the Miller squared code, which contains no l.f. or d.c. component, and by setting the heads on the spinning drum with their azimuths at +15° and −15°, they have eliminated the need for a guard-lane between adjacent recorded tracks (Fig.2). Even though the recording head's footprint is actually wider than the track pitch, the arrangement has excellent immunity to errors. The minimum configuration is two head pairs, with a tape-wrap around the drum of a little more than 180°.

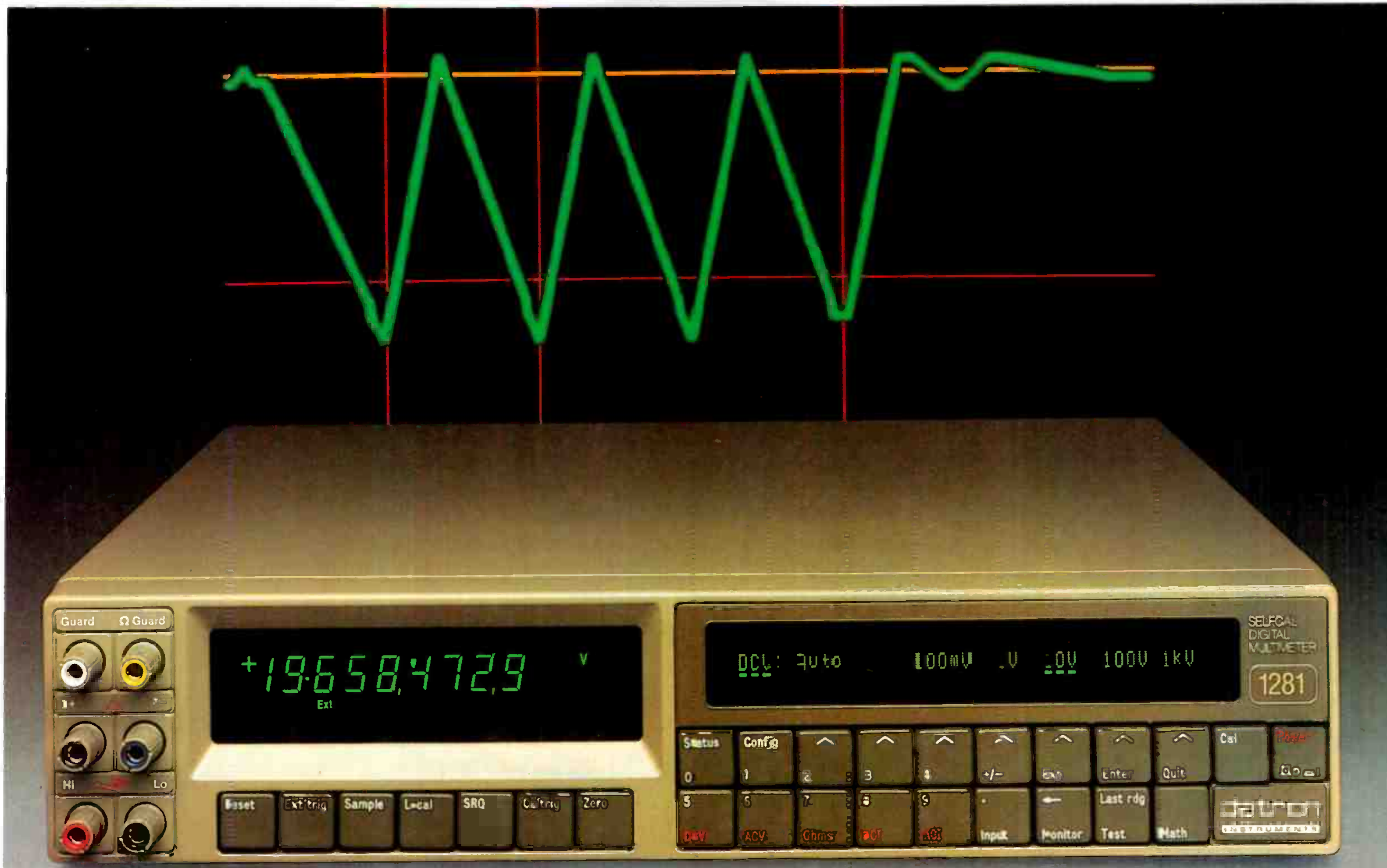
D2's error handling strategy is a two-dimensional Reed-Solomon code capable of correcting burst errors at least 1900 bytes long, or two picture lines. Since each head of a pair records at half the data rate ($2f_{sc}$), a usable picture can be recovered even if one fails. No flying erase head is required because the signal can be erased by overwriting.

The azimuth recording technique enables the four audio tracks to be placed at the edges of the tape, despite the fact that any tracking error is likely to be higher there. In the D1 format – for safety – the audio blocks occupy the centre of the tape even though this creates difficulties with variable-speed playback. Since the start of each field follows a set of audio blocks, reproducing a frozen frame in D1 entails reading twelve tracks (the length of a field), then jumping back over those tracks within the brief duration of the audio blocks. With D2, 180° of drum rotation is available for relocating the heads.

Audio is sampled at 48kHz and encoded into 20-bit samples. Each sample is recorded twice, giving an extra 7.7Mbit/s of data.

The new format is claimed to allow copying through up to 20 generations without unacceptable degradation of quality; though experience at the BBC suggests that about eight encode-decode cycles may be more realistic. But with back-to-back digital copying, tapes could be cloned indefinitely.

One of Ampex's first D2 machines will be the replacement for its ACR-25 quadruplex machine for commercial spots. Its companion will be a machine for general studio use; Ampex hopes that this will replace the present C-format machines. Further D2 machines are on the way from Sony, Ampex's partners in developing the format. Prices are likely to be about the same as for C-format types.



Self-calibrating digital multimeter

A method of internal calibration together with innovative circuit design produces a higher accuracy than previous designs.

HAL CHENHALL

Instruments for calibration and standards purposes need to be an order of magnitude better than the equipment to be calibrated. Precision digital multimeters already take full advantage of the inherent qualities of the critical components that define the instruments' performance, and can therefore achieve high accuracy. Calibration meters consequently need to provide even greater accuracy.

New circuitry and a method of internal calibration, which can be linked to external standards, are provided in the Datron Instruments' 1281 digital multimeter to produce very high performance across teh complete range of its functions. It is considerably more accurate than known previous designs while retaining a compact size and without being over expensive. The instrument is particularly intended for use in standards and calibration laborоratories and is designed to be easy to use, despite its high level of accuracy and its wide range of functions.

There are four main design areas where significant advances have contributed to the overall instrument performance – analogue to digital converter, master reference, a.c. measurement, and self-calibration.

ANALOGUE TO DIGITAL CONVERTER

A multi-ramp, multi-cycle integrator has been developed to provide the necessary performance for an 8½ digit instrument. The main elements inherited from the quad-slope technique used in Datron's previous Autocal range of instruments are the use of feedforward bias signals to overcome problems at zero due to noise in the null detector, and the use of two reference values V_{ref} and $V_{ref}/16$ (coarse and fine ramps) to provide speed and accuracy, Fig. 1. The additional features which provide the improvements include:

- Use of multiple cycles which means that a smaller integrator capacitor can be used, reducing dielectric absorption effects and improving linearity.
- Applying signal and reference inputs at the same time rather than separately during multi-cycle conversions, improving conversion speed.
- Using both positive and negative references an equal number of times for every conversion, ensuring that reference switching errors are constant and can be removed by an integral autozero cycle.
- Using a custom asic for the a-to-d conversion control, providing flexibility in programming integration times and resolution.
- A dynamic autozero system avoids the need for the more common sample and hold type of autozero circuit, which can become saturated at overload and slow down overload recovery.

When the a-to-d converter is not actually converting a signal, it goes into a reset or 'dynamic autozero' mode. This maintains the output of the already low drift integrator near zero by applying small amounts of $-V_{ref}/256$ and then nulling it with $+V_{ref}/256$. Because this reset cycle is short (50μs) and occurs at least once before each conversion, it avoids the need for the random interruptions for zero corrections found in less sophisticated conversion techniques.

The output of the integrator during a dynamic autozero cycle is shown in Fig. 2. Initially, zero signal is applied to both signal and reference inputs for a set period. Then, $-V_{ref}/256$ is applied to the reference input and the output of the integrator 'ramps up' and passes through null. After the null, $-V_{ref}/256$ is applied for a fixed period so that the integrator overshoots. Zero is again applied for a short period to both signal and reference inputs, to ensure that both references are not accidentally applied to the integrator simultaneously. Then with $+V_{ref}/256$ switched to the reference input, the integrator ramps down towards and beyond null and for a predetermined period.

The cycle is then repeated, maintaining the integrator output near zero. At the end of each cycle the integrator is in exactly the same place, even though the integrator may drift between resets.

SINGLE-CYCLE CONVERSION

Depending on read rate and resolution requirements, the converter can make either single-cycle conversions. Some of the key elements of the conversion technique are well illustrated by considering the single-cycle conversion of Fig. 3.

On receipt of a reading conversion command, the last reset cycle is completed within a fixed delay of 50μs, and then the signal is applied to the signal input. The integrator ramps up and after a fixed period a feedforward bias of appropriate polarity ($+V_{ref}$) is fed to the reference input while the Signal is still being applied. Next, zero is applied to both the signal and reference inputs for a fixed delay to ensure that the system does not attempt to switch in both references at the same period where $-V_{ref}$ is applied to the reference input. Eventually the integrator crosses null and is allowed to overshoot to synchronize to a clock signal. This represents the end of the coarse conversion period and the integrator then configures itself for the final, more accurate or 'fine', stages of the conversion.

Firstly, zero is applied to the signal and reference inputs to avoid the effects of any switching transients, followed by applying $+V_{ref}/16$ to the reference input for a fixed time. The polarity of reference used in the cycle at this point is chosen to ensure that the approach to zero for the final ramp is always made using the $+V_{ref}/256$ reference, irrespective of signal polarity. This overcomes any non-symmetry in null detector response times. After another dead period, $-V_{ref}/16$ is applied to the reference input so that the integrator heads back again to null and overshoots.

At the end of the final dead period, $+V_{ref}/256$ is applied to the reference input. This is the last part of the conversion and its final stages are identical to the end of the dynamic autozero cycle. In other words, the integrator output finished back exactly where it started, so that the charge from the signal has been exactly balanced by the charge from the various references. At the end of the conversion the a-to-d converter goes back into dynamic autozero mode and the reading data may be shifted out of the control circuits.

The sequence for a negative polarity signal is subtly different from that for the positive polarity signal described but the important fact is that for every conversion each reference is switched in and out once, and that the final ramp down is identical for both signal polarities. This means that any reference switching errors due to charge injec-

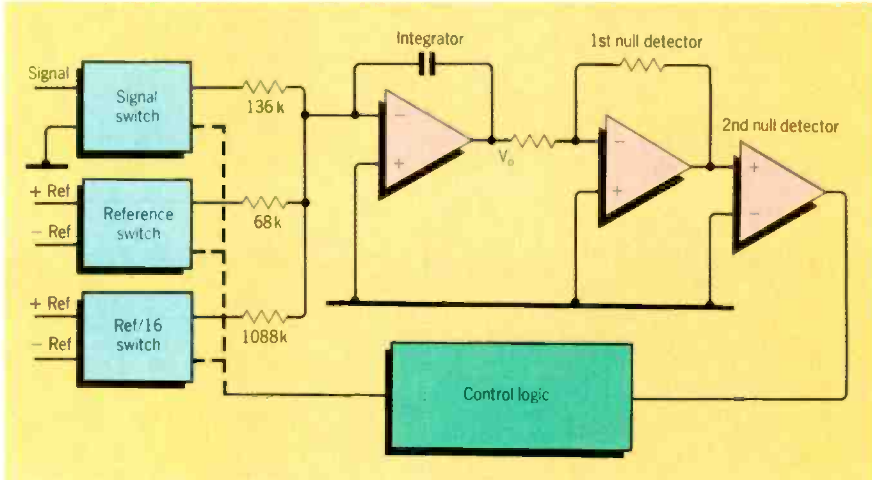


Fig.1. Multiple references are used with the multi-slope analogue-to-digital converter in order to increase conversion speed without losing accuracy in detecting the final null.

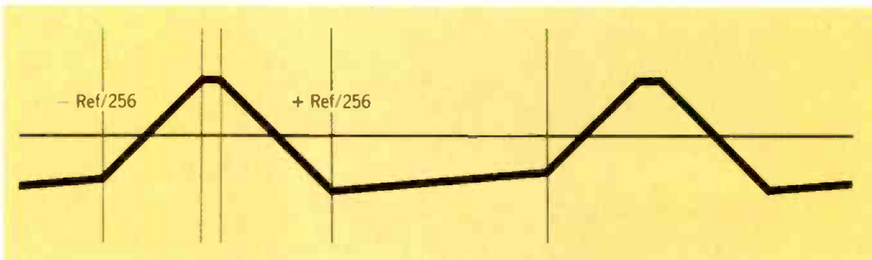


Fig.2. A dynamic autozero cycle is used by the analogue-to-digital converter to maintain the integrator output near zero when no conversion is being done. The end of the +Ref/256 period is used as both the starting and finishing point for every conversion, ensuring an exact charge balance.

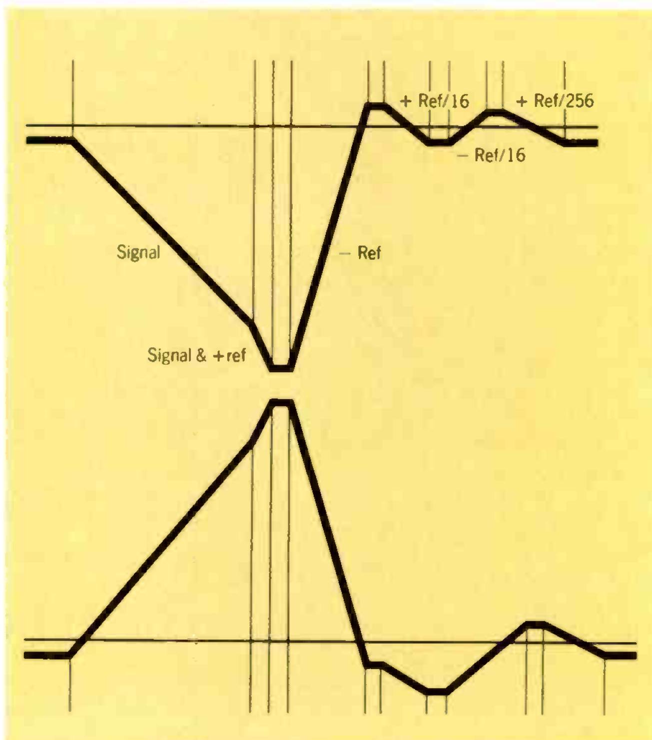


Fig.3. Conversions are subtly different for different polarity input signals. This ensures that the final slope to null is always made with +Ref/256, avoiding possible null detector hysteresis. At the end of each conversion the integrator output is exactly where it started from, which means that all charge from the unknown input has been balanced by the charge from the known references.

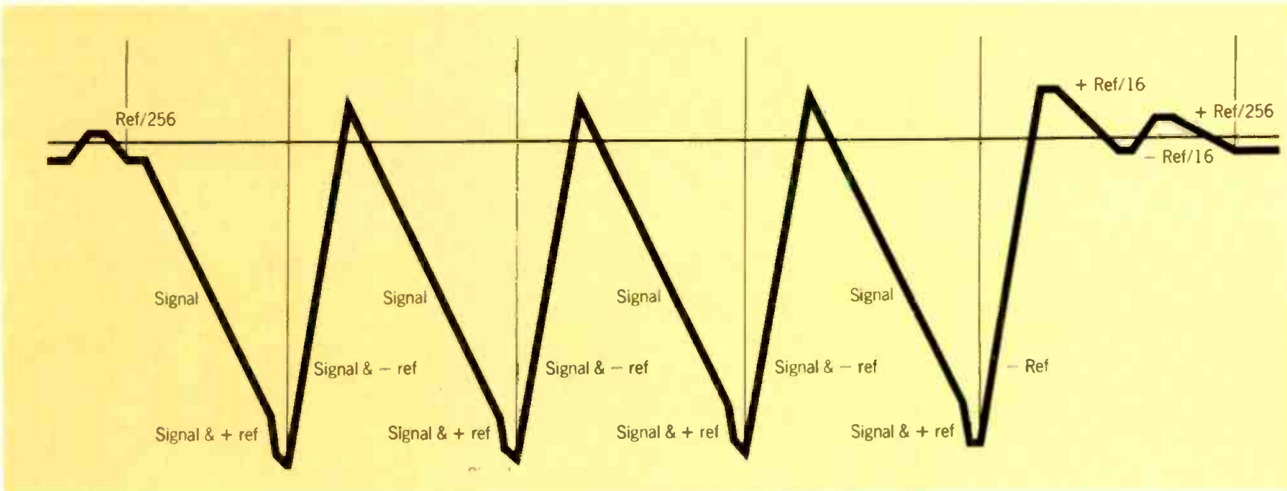


Fig.4. Multiple cycle conversions allow the signal to be applied to the integrator for almost the entire conversion period, which improves the speed of conversion. It avoids the need for a large integrator capacitor and the associated dielectric absorption problems.

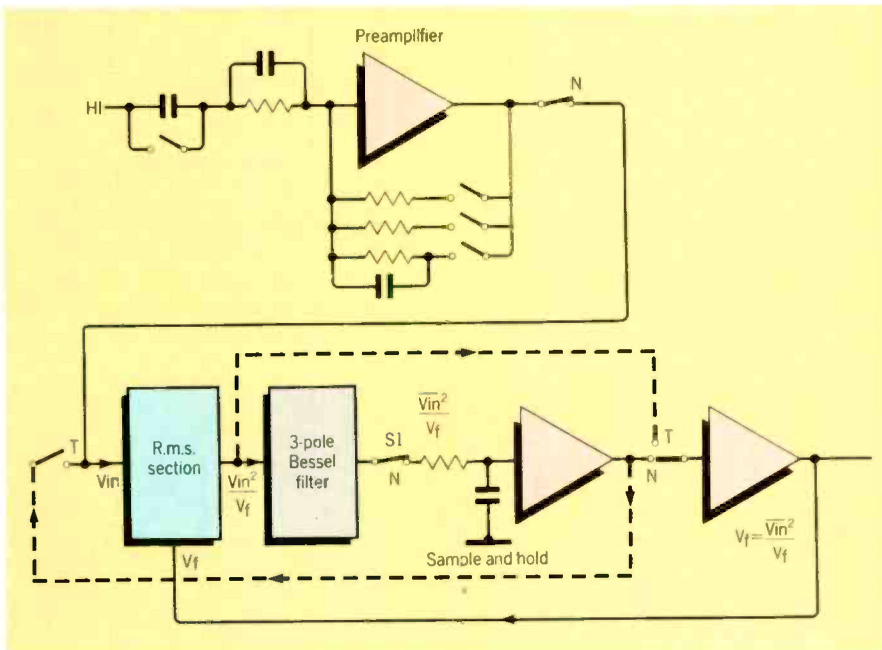


Fig.5. An automatic ac/dc transfer feedback technique can be used to calibrate the gain of the electronic r.m.s. section for each reading. This is useful for removing time and temperature drift from this part of the circuit

tion are balanced for all conversions, while any small null detector delay time errors and charge injection effects due to the final ramp are automatically removed by the dynamic autozero.

MULTI-CYCLE CONVERSION

A multi-cycle design was chosen to give maximum flexibility to the available integration periods without forcing the need for a large integrating capacitor, which could have introduced greater dielectric absorption problems. Instead, a small integrator capacitor is used, and longer integrator periods are achieved by ramping up and down several times while specifically avoiding saturation of the integrator. In addition, the multi-cycle approach provides effective gain in the integrator, reducing the requirements placed on null detector sensitivity and making higher accuracy conversions easier to achieve.

One of the key features of this particular multiramp design is that, for all but the final ramp, the signal is applied continously and the various references are applied simultaneously with the signal at the appropriate times (Fig. 4). In other words, the integrator effectively ramps up and ramps down at the same time, which significantly reduces the time to take a reading.

Timing and counting considerations with this design are complex. Although the a-to-d converter always performs the same sequence, great flexibility of control is exercised over its performance through the use of programmable delay timers, a ramp timer and a counter for the number of ramps performed. All of these timers and counters are integrated into a custom asic which has a 32 bit control register programmed by the instrument's microprocessor via a special serial interface. The same serial loop is used to transmit the reading from the asic to the processor for calibration and display.

MASTER REFERENCE

The reference used in the analogue to-digital conversions derived from two specially conditioned zener reference modules. Each reference module contains the reference device and its associated buffer circuits, all hermetically encapsulated together to ensure constant temperature across the module. The modules are stable to within ±2 p.p.m per √year, produce noise of less than 0.1p.p.m, and have temperature coefficients of better than 0.1p.p.m/°C. This temperature coefficient is held over a wide temperature span of 0 to 50°C, and the references exhibit negligible temperature shock hysteresis. The master reference is obtained by summing the outputs from both reference modules.

Extensive evaluation of the modules has resulted in a burn-in process which equates to an ageing of 1 year, reducing both infant mortalities and hysteresis effects. Following this process, the modules are checked over a temperature span of 0 to 70°C for temperature performance, and then monitored for long-term drift over a minimum period of three months.

A.C. MEASUREMENT

The inverting preamp has to provide good flatness from d.c. to 1MHz and a minimum of offset voltage at its output to ensure good d.c.-coupled performance. A complex design is required to achieve this, using several gain elements in conjunction with each other.

The closed-loop gain is set by range resistors and capacitors. Because of the presence of stray capacitance around the preamp, the input and feedback resistors setting the low frequency gain have to be shunted by capacitors to compensate for this. At high frequency, it is these capacitors that determine the closed-loop gain. The feedback capacitance on each range is effectively trimmed at calibration using a ladder network digital-to-analogue converter driven from the microprocessor to control the channel resistance of fets in the gain-defining network. Extensive bootstrapping of components in the preamp feedback area reduces the effect of stray capacitance.

ELECTRONIC R.M.S.

An electronic r.m.s. technique has the following advantages over designs on thermal techniques:

- Higher accuracy – the instrument achieves ±90p.p.m 1 year uncertainties, which is the best available in any commercial d.m.m.
- Faster response – the instrument can take high accuracy 6½ digit a.v. readings at a rate of one per second, about six times faster than other commercial designs.
- Wider dynamic range – the span from 100nV to 1000 r.m.s. can be covered in fewer ranges, saving cost and space. Each range can accept inputs from 1% of range to 200% of range.
- Good crest factor performance for non-sinusoidal signals (5:1 at full range, 10:1 at 25% of range).

The principles behind the r.m.s. conversion technique are shown in Fig. 5. With the instrument set to its 'normal' mode, the signal from the preamp is full-wave rectified by the combined operation of the rectifier and the log.amp. and taken as a current input to the input of the r.m.s. section. This is a current-operated device, whose output is unidirectional but peaky and converted to a voltage for smoothing by a three-pole Bessel filter.

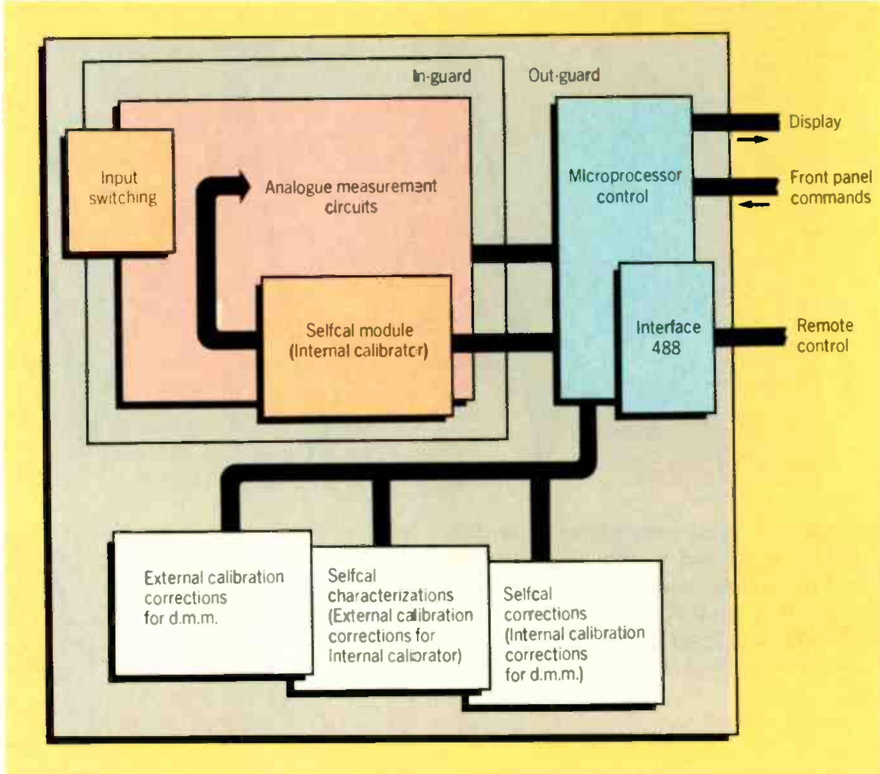


Fig.6. Separate calibration memories are used to store the external calibration corrections for both the d.m.m. and the internal calibrator. An additional calibration memory is used to store selfcal corrections derived during an internal calibration.

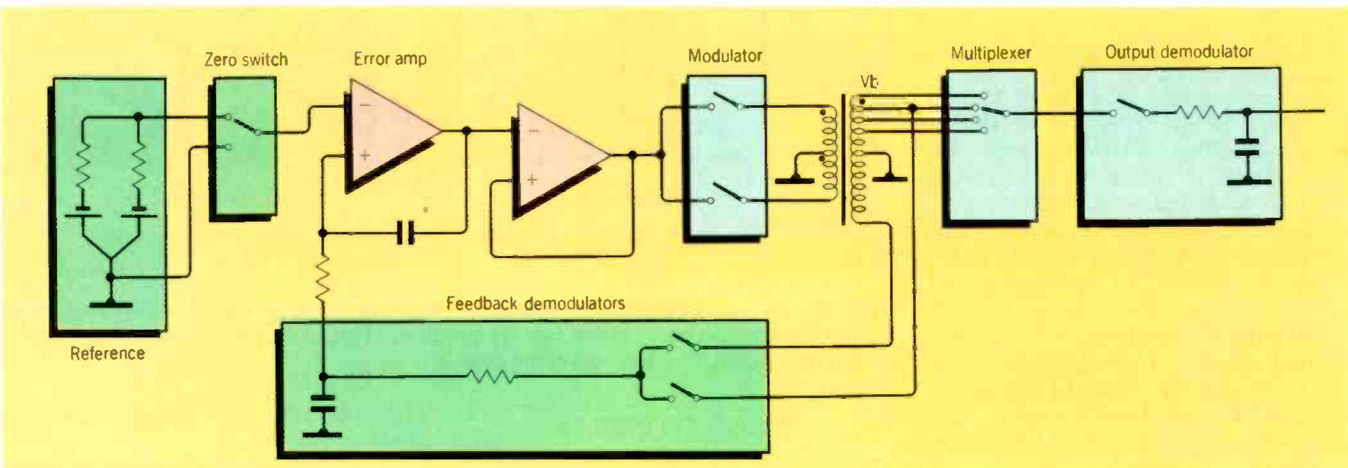


Fig.7. Different levels of d.c. calibration voltages are produced by modulating a d.c. reference and passing the resulting square wave through a transformer. The various output tappings are connected to a sample and hold to reconstitute a d.c. level. A feedback technique is used to ensure a perfect turns-ratio performance which is inherently stable.

The filter is chosen for its optimum settling time, and offers selectable configurations to permit operation down to 1Hz. A sample and hold with isolating buffer provides further one-pole filtering above a certain frequency, after which the smoothed signal is taken to an amplifying buffer which drives the instrument's analogue to digital converter. The output signal V_f is equivalent to $\overline{V_{in}}^2/V_f$ by virtue of the action of the electronic r.m.s. section on its two inputs of V_{in} and V_f. This means that $V_f = \sqrt{(V_{in})^2}$, the r.m.s. of V_{in}.

A.C.-TO-D.C. TRANSFER TECHNIQUE

The a.c. circuit employs a refinement on the basic technique which uses an a.c.-to-d.c. transfer mechanism to calibrate the gain of the r.m.s. converter.

Consider Fig. 5, with all swiches set to 'normal' mode (N). When a signal (Y_0) is passed through the r.m.s. converter, a d.c. equivalent value (Y_1) is produced. For an ideal converter $Y_0=Y_1$, but assuming the converter has a gain other than unity, then $GY_0=Y_1$. This gain factor G may drift with time and temperature, and the purpose of the a.c.-to-d.c. transfer technique is to remove these effects. This is achieved by setting all swiches to 'transfer' mode (T) and opening S_1. Signal Y_1 is sampled and held, and then fed back through the r.m.s. converter to obtain another value, Y_2. In this case, $GY_1=Y_2$ and as Y_1 and Y_2 are known, the true value of G can be determined. This can then be used to give a value for Y_0, corrected for the r.m.s. converter gain, i.e.

$$Y_0=Y_1/G=Y_1^2/Y_2.$$

The actual sequence used in the d.m.m. is more to overcome the problems associated with ripple on the measurements. When the reading Y_1 is taken, the a-to-d converter integration time can be arranged to smooth out any ripple on the signal emerging from the Bessel filter. However, as soon as the switch S_1 beyond the filter is opened, the sample and hold will potentially capture the peak of any ripple on the signal and so not be representative of the desired d.c. level (Y_1). An additional measurement is taken with only switch S_1 open (and all other switches set to N) to give a value Y_3 which is the correct value for the determination of $G(GY_3=Y_2)$.

The required calculation to correct for gain is therefore $Y_0=Y_1/G=Y_1Y_3/Y_2$.

Spot frequency enhancements. To enhance a.c. performance even further, each a.v. range can be spot calibrated at up to six independent user defined frequencies, such that, when the instrument is making measurements of signals at frequencies which lie within ±10% of these points, flatness errors are reduced improving accuracy to ±65p.p.m. for a whole year. In addition, the instrument has a reciprocal counter function designed into one of its custom asics which can display the frequency of an a.v. signal at the same item as its r.m.s. value is being shown on the main display.

RESISTANCE AND CURRENT

The wide selection of floating current source ranges provided by the resistance function means that a variety of resistance measurement modes can be offered to suit many different application areas. For example, when operating in its normal mode, the instrument's current sources are optimized for low noise and best accuracy. However, where low compliance or low open-circuit voltages across the d.m.m's terminals are needed, a special low current mode can be selected. Applications where this can be useful include in-circuit measurement of components in parallel with diode junctions, or the measurement of temperature using platinum resistance thermometers, where the self-heating of the current passing through the resitive element may be important.

For applications where external thermal e.m.fs present measurement problems, a mode is provided where a zero reference reading is automatically taken with the measurement current turned off. This zero mesurement is subsequently subtracted from that made with the current flowing to give a resultant value where the effect of any thermal emfs have been eliminated.

External errors produced by specific connections can be reduced using four-wire sensing and guarding techniques. Four-wire sensed measurement can be made with up to 100Ω in any lead with no significant degradation in accuracy. Furthermore, errors caused in external leakage paths can be eliminated using an 'ohms guard' terminal which may also be used for incircuit measurement of components in parallel with other resistive elements.

SELF-CALIBRATION

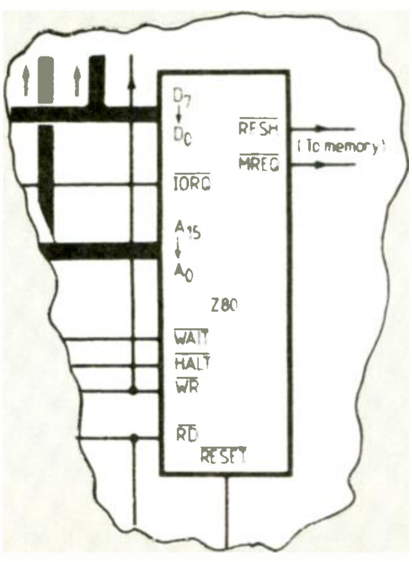
The performance of the instrument is limited by the basic stability of the gain-defining resistor networks used in signal conditioning amplifiers and the zener devices which form the instrument's basic voltage reference. To push performance beyond some of these limitations, the instrument makes extensive use of internal calibration – 'Selfcal' – to remove the effects of time and temperature drift in almost all areas. Using only a transformer multiplier and two precision resistors (and considerable software), enough internal accurate sources can be produced in conjuction with the d.m.m's normal measurement circuits to enable correction of drift in almost all key areas. The major exception to this is drift in the zener references because the Selfcal process relies on deriving its basic calibration signals for these components.

The result is a 2:1 improvement in temperature coefficient and a 35% improvement in performance over the identical instrument when used without Selfcal. This means the instrument is capable of maintaining its standards lab performance over long periods of time and even in a factory floor environment. Selfcal is activated with a single key press or GPIB command, and requires no external calibration sources.

Periodically, the multimeter is electronically calibrated against traceable external standards, when any differences in readings compared to the value of the external calibration sources can be used to derive calibration constants which are stored by the instrument in non-volatile memory. These external calibration corrections subsequently serve to automatically correct all readings taken by the multimeter.

At the same time as the d.m.m. is being externally calibrated the internal calibrator is also traceably calibrated by comparing the readings taken by the meter on any particular range against external standards with those made using its internal Selfcal sources. In effect the d.m.m. is used as a transfer device to calibrate the internal calibrator against the external standards, with the characterization factors being stored in the non-volatile memory alongside the instrument's normal external calibration corrections.

At a later date, when the multimeter user decides to 'Selfcal' the instrument, a single key press will cause another set of internal measurements to be made but using only the internal calibrator to calibrate the d.m.m. circuits, Fig. 6. The new set of readings are compared against the corresponding characterized values and any differences between the two recognized as errors which can be compensated for by the microprocessor in all subsequent measurements. A third set of calibration constants – the Selfcal corrections – are stored alongside the original external calibration constants and the internal calibrator characterization factors.



Z80 bootstrapping and communication interface
Please accept our apologies for omitting these references from John Cooke's Circuit Idea in the April issue.

BOOKS

Loudspeaker and Headphone Handbook edited by John Borwick, Butterworths, 573 pages, £57.50. Comprehensive audio engineer's reference work covering all aspects of loudspeakers from principles of sound radiation to subjective evaluation. Of its fourteen sections, each written by an authority in the audio field, six cover the actual drivers and their enclosures, and seven cover wider aspects of loudspeakers like the listening environment, public address systems, loudspeaker measurements and subjective evaluation.

There is no doubt that this is a useful, authoritative and detailed handbook, with no shortage of diagrams, graphs, equations and circuits. It is not all hard facts either. In his section on multiple-driver loudspeakers for example, Laurie Fincham of KEF says, "to date there is no conclusive scientific evidence to show that linear phase is a necessary requirement for high-quality reproduction. Improvements in both source material and transducers, however, may show that linear-phase designs are superior."

And Desmond Thackeray of Surrey University will upset the sub-woofer enthusiasts in his section on loudspeaker enclosures. He says, "It may seem a little anomalous that so much effort and ultimate cost to the purchaser, is directed towards perfecting the bottom octave of the audio spectrum, where our ears are in any case less sensitive and less discriminating; for the sounds in this octave from most programme sources may sometimes be little more than 'audio sludge' when heard alone".

At only 16 pages, Thackeray's section on enclosures seems a little short, and at 88 pages, Baxandall's discussion of electrostatic loudspeakers may seem a little long when you consider that the book doesn't mention piezo-electric drivers at all as far as we can see. Nevertheless, we are sure that every audio engineer will find the book useful.

M.E.E.

Elliptic filter design

Computation of zeros and poles for both odd and even-order elliptic filters can be carried out in four approximation steps without making elliptic integrals.

KAMIL KRAUS

The approximation method described here is based on Darlington's work on odd-order filters[1]. I found that Darlington's method could be expanded to encompass even-order filters, resulting in a powerful tool for computer-aided filter design.

Symbols used in the approximation method are shown in the panel. In Darlington's paper, an elliptic odd-order filter is described with pass and stop bands defined as, $0 \leqslant \omega \leqslant \omega_c$ and $\omega \geqslant \omega_s$ respectively. The low-pass transfer function can be derived from the equation,

$$\frac{\text{Power out}}{\text{Power in}} = P(y_0^2) = \frac{\text{constant}}{1+K^2 I_0^2 F_0^2(y_0)}$$

where $y_0 = \omega/(\omega_c \omega_s)^{1/2}$. Constant K is fixed by the reflection coefficient according to the expression,

$$K = \frac{\rho/100}{\sqrt{1-(\rho/100)^2}}$$

In Darlington's paper, variable y_0 and the appropriate transfer function F_0 are defined as follows,

$$y_0 = \frac{1}{2a_0}\left(y_1 + \frac{1}{y_1}\right), |y_1| \geqslant 1$$

$$y_{0k} = \frac{1}{2a_0}(y_{1k} + \frac{1}{y_{1k}}), |y_{1k}| \geqslant 1$$

$$F_0(y_0) = \frac{1}{2I_0}\left[F_1(y_1) + \frac{1}{F_1(y_1)}\right]$$

$$F_1(y_1) = y_1 \prod_{k=1}^{m} \frac{1-y^2_{1k} y_1^2}{y^2_1 - y^2_{1k}}$$

where y_{1k} represents constants related to transmission zeros, and hence to poles, and $a_0 = (\omega_s/\omega_c)^{1/2}$. How I_0 can be computed is shown later.

Darlington then found that the approximation can be carried out in four steps, resulting in accuracy sufficient for practical designs.

NEW APPROXIMATION METHOD

In the following approximations, methods for computing a_m, y_{m-1}, I_{m-1}, S_m and s_m for input values k, n and K are shown, summarized as follows.

$$a_0 = \sqrt{\frac{1}{\sin\alpha}}$$

$$a_m = a^2_{m-1} + \sqrt{a^4_{m-1} - 1}$$

for m = 1, 2, 3 and 4,

$$y_4 = \frac{a_4}{\cos(k\pi/2n)},$$

and

$$y_{m-1} = \frac{1}{2a_{m-1}}\left(y_m + \frac{1}{y_m}\right)$$

for m=4, 3, 2 and 1. The transmission on zero is then $\Omega = a_0 y_0$. Next,

$$I_4 = 2^{n-1} a_4{}^n$$

and

$$I_{m-1} = \sqrt{1/2\left(I_m + \frac{1}{I_m}\right)}$$

for m=4, 3, 2 and 1. The minimum attenuation in the stop band, A_{min} is, $10\log(1+K^2 I_0{}^4)$. Now,

$$s_0 = \frac{1}{KI_0}$$

$$s_1 = \frac{1}{K} + \sqrt{\frac{1}{K^2} + 1}$$

$$s_m = I_{m-1} S_{m-1} + \sqrt{(I_{m-1} S_{m-1})^2 + 1}$$

for m=2, 3 and 4 and,

$$s_{50} = I_4/S_4 + \sqrt{(I_4 S_4)^2 + 1},$$

$$s_5 = s_{50}\exp\left(j\frac{k}{n}\phi\right).$$

Here, ϕ is 360° and 270° for odd and even-order elliptic filters respectively.

The poles are then,

$$s_m = \frac{1}{2a_m}\left(s_{m+1} - \frac{1}{s_{m+1}}\right)$$

for m=4, 3, 2 and 1.

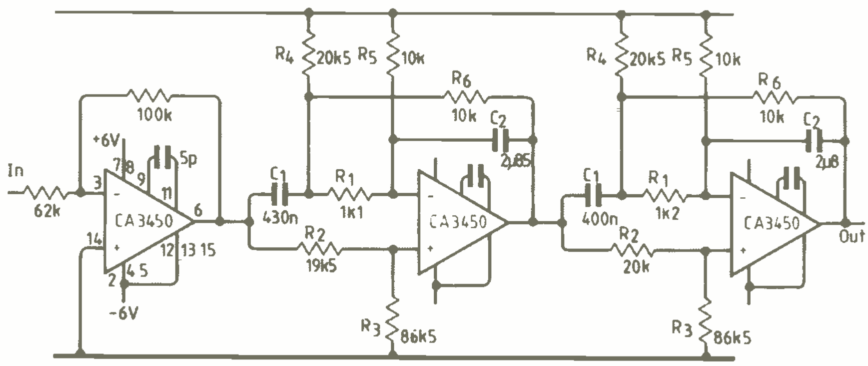


Fig 1. Fourth-order low-pass elliptic filter using fast op-amps.

Table 1. Comparison between Christian and Eisenmann's tables and results obtained using the new approximations.

	Published values	Approximated results
A_{min}	55.6dB	55.595dB
Ω_2	2.7538868301	2.753885470
Ω_4	6.4585483632	6.458556093
$s_{1,2}$	−0.1875829230 ±j1.0503250899	−0.1875826282 ±j1.050325741
$s_{3,4}$	−0.5117132703 ±j0.4633480507	−0.5117128388 ±j0.4633481372

Table 2. Computed component values for the first and second stages of the filter, Fig. 1.

Comp.	Stage 1	Stage 2	Unit
R_1	0.1186104986	0.1871868891	Ω
R_2	1.9510762510	1.6625721170	Ω
R_3	8.674880680	8.5561733990	Ω
R_4	2.0514404060	2.5092696700	Ω
$R_{5,6}$	1	1	Ω
C_1	0.085702151	0.2954123197	F
C_2	5.687866212	1.3490376170	F

FILTER EQUATION SYMBOLS

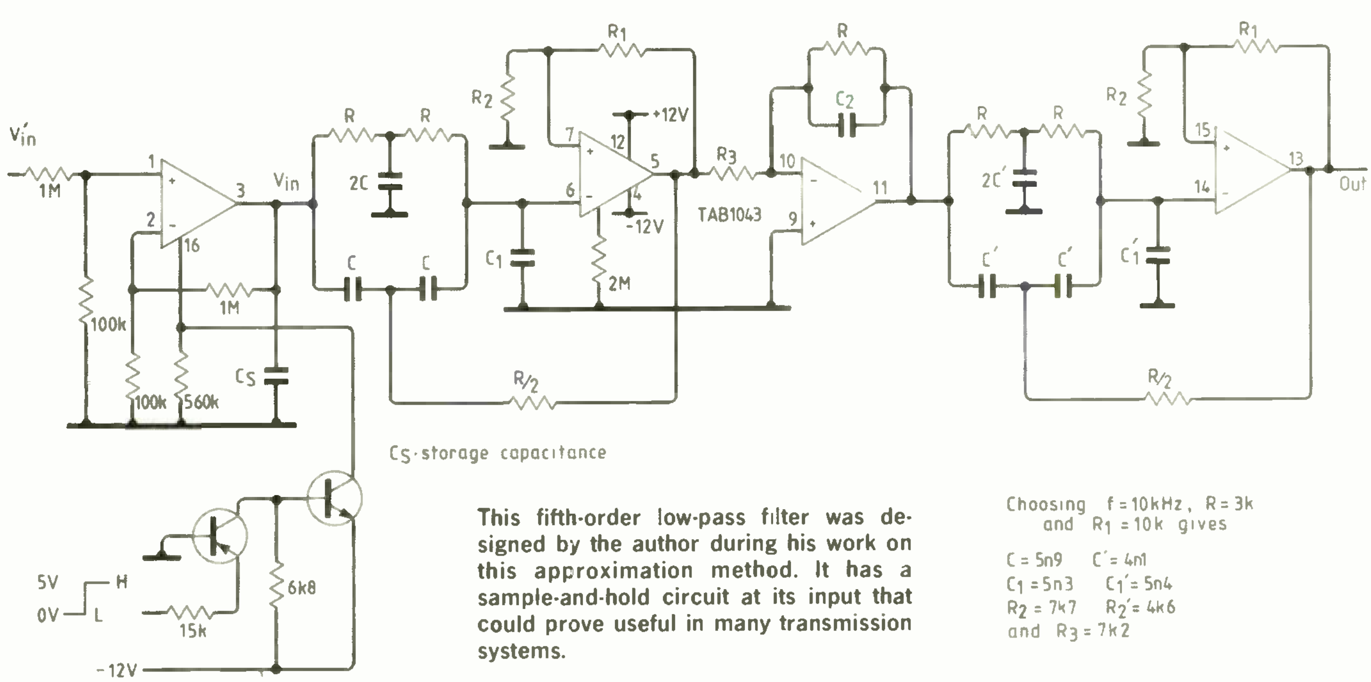
n	=	filter order, k=1,3,5,...≤n
α	=	modular angle
ρ	=	reflection coefficient
Ω	=	attenuation zero
ε	=	ripple factor
ω_s	=	stop band cut-off frequency
ω_c	=	pass band cut-off frequency
s_m	=	pole
A_{min}	=	minimum attenuation in stop band
A_{max}	=	maximum attenuation in pass band

To review this method, I have made a comparison with Christian and Eisenmann's tables[2] for n=4, ρ=25% and α=23°, Table 1.

EXPERIMENTAL CIRCUIT

To prove the method experimentally, I worked out the circuit design[3] shown in Fig. 1, the

FIFTH-ORDER LOW-PASS FILTER WITH INPUT SAMPLE-AND-HOLD



This fifth-order low-pass filter was designed by the author during his work on this approximation method. It has a sample-and-hold circuit at its input that could prove useful in many transmission systems.

transfer function of which is given by,

$$F_s = A_1A_2F_1(s)F_2(s).$$

Constants A_1 and A_2 may be estimated assuming that,

$$A_1\left|F_1(j0)\right| = \frac{1}{\sqrt{1+\epsilon^2}}$$

Constant A_1 is 0.0264240112 and A_2 is 0.0608407608 so,

$$A = A_1A_2 = 0.0016076569 \rightarrow 1/A = 622.0232.$$

Constant A is realized by the first op-amp in Fig.1. Values for the first and second filter stages were computed using the Cioffi algorithm[1] and are as shown in Table 2.

To obtain practical values for the design, scaling factors $f_R = 10^4$ and $f_c = 200$ were used. Frequencies up to 150MHz can be handled by the CA3450 op-amp shown in Fig.1.

References

1. Darlington, S., Simple algorithms for elliptic filters and generalization thereof. *IEEE Transactions on Circuits and Systems*, vol. CAS25, No 12, pp. 975-980, Dec. 1978.
2. Christian, E. and Eisenmann, E., Filter design tables and graphs, Transmission Networks International Inc., Knightdale, NC, 1977.
3. Boctor, S.A., Single amplifier functionally tunable low-pass notch filter, *IEEE Transactions on Circuits and Systems*, vol. CAS22, No 12, pp. 875-881, Dec. 1975.
4. VanValkenburg, M.E., Analog filter design, Holt, Rinehart and Winston, New York 1982.

Tech Talk on BBC

What appears to be the only regular radio programme devoted wholly to engineering is back on the BBC World Service after a successful pilot series last autumn.

In 'Tech Talk', reporters visit engineering projects both in Britain and abroad to learn about them from the people on the spot. Previous programmes have investigated a computer-controlled flexible manufacturing system at Austin-Rover, discovered how transputers are being adapted for use in space, and toured STC's optical fibre factory.

However, electronics is not the only branch of engineering the programme aims to cover. In the first of the new series, presenter George Macpherson visited a large civil engineering project now under way at Charing Cross Station, where construction workers are tackling the problem of how to erect a £70M office block above the tracks without disrupting London's trains.

Tech Talk is broadcast weekly on Mondays at 11.15 GMT, Tuesdays at 08.15 and Fridays at 02.15. BBC World Service is heard in the UK on 648kHz (463m) medium wave, and on numerous short-wave channels.

Tech Talk presenter George Macpherson (right), seen here with producer Martin Redfern, braved the height and the pigeons of Nelson's Column to discover how epoxy resins with very low surface tensions have been injected under high pressure to preserve the stonework and fill cracks.

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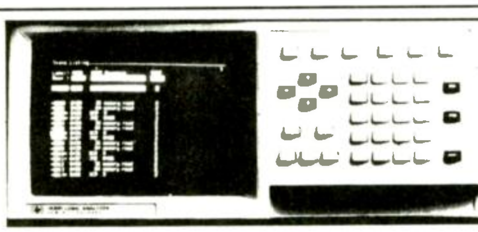

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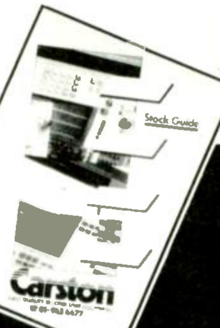

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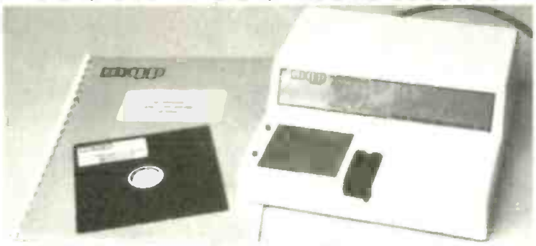

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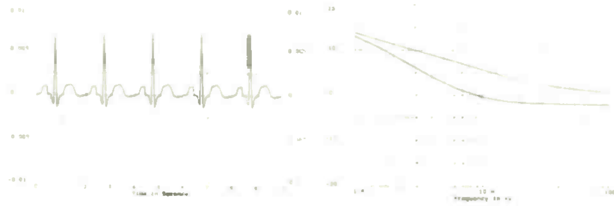

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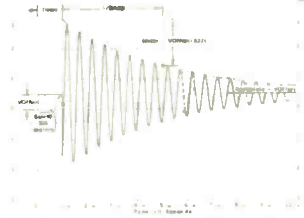

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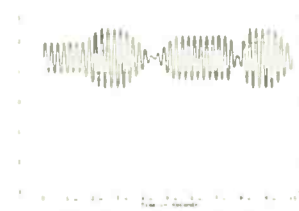

Waveform through modulating circuit with offset

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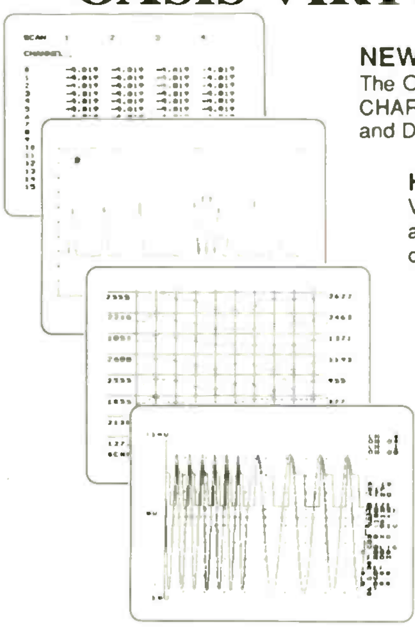

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D-to-a conversion step removal

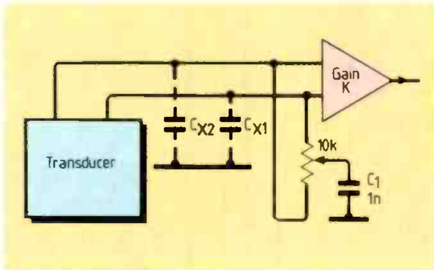
Digital-to-analogue converters produce stepped outputs that require further processing to recover an original waveform. This circuit converts these steps into a series of ramps using a method that allows a range of sample frequencies.

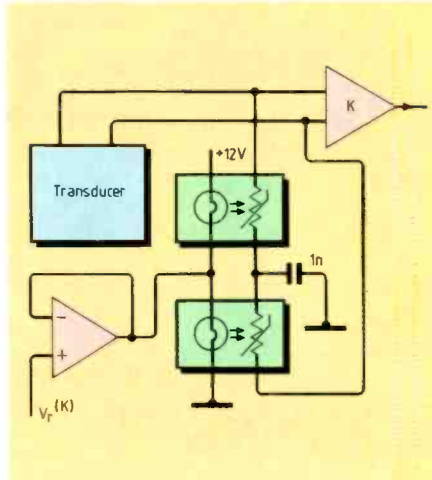
Comparing a ramp at sample-rate f_s with a sawtooth at frequency $f_x > f_s$ produces a sequence of pulses of varying mark-to-space ratio. These are inverted on alternate samples by an exclusive-Or gate because the two latches are clocked on alternate samples and exchange their roles of 'present' and 'previous' data with each sample.

When the f_x components have been removed by the filter, the steps become a series of ramps. With values shown, f_x is 200kHz and f_s can range from 5kHz to 200kHz; speed of response to changes in f_s, determined by R and C, is around 5ms.

I developed the circuit for use in a music synthesizer but it could be adapted for storage oscilloscopes. Further filtering may be needed to remove residual f_x components. For operation at lower frequencies or for a single sample frequency the circuit could be greatly simplified.

K.J. Biggs
Impington, Cambridgeshire

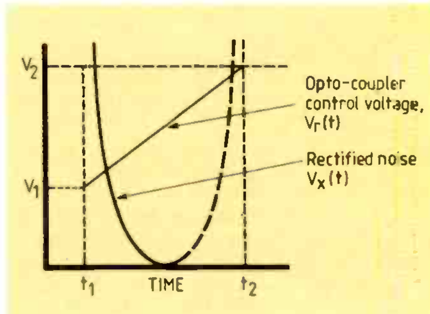


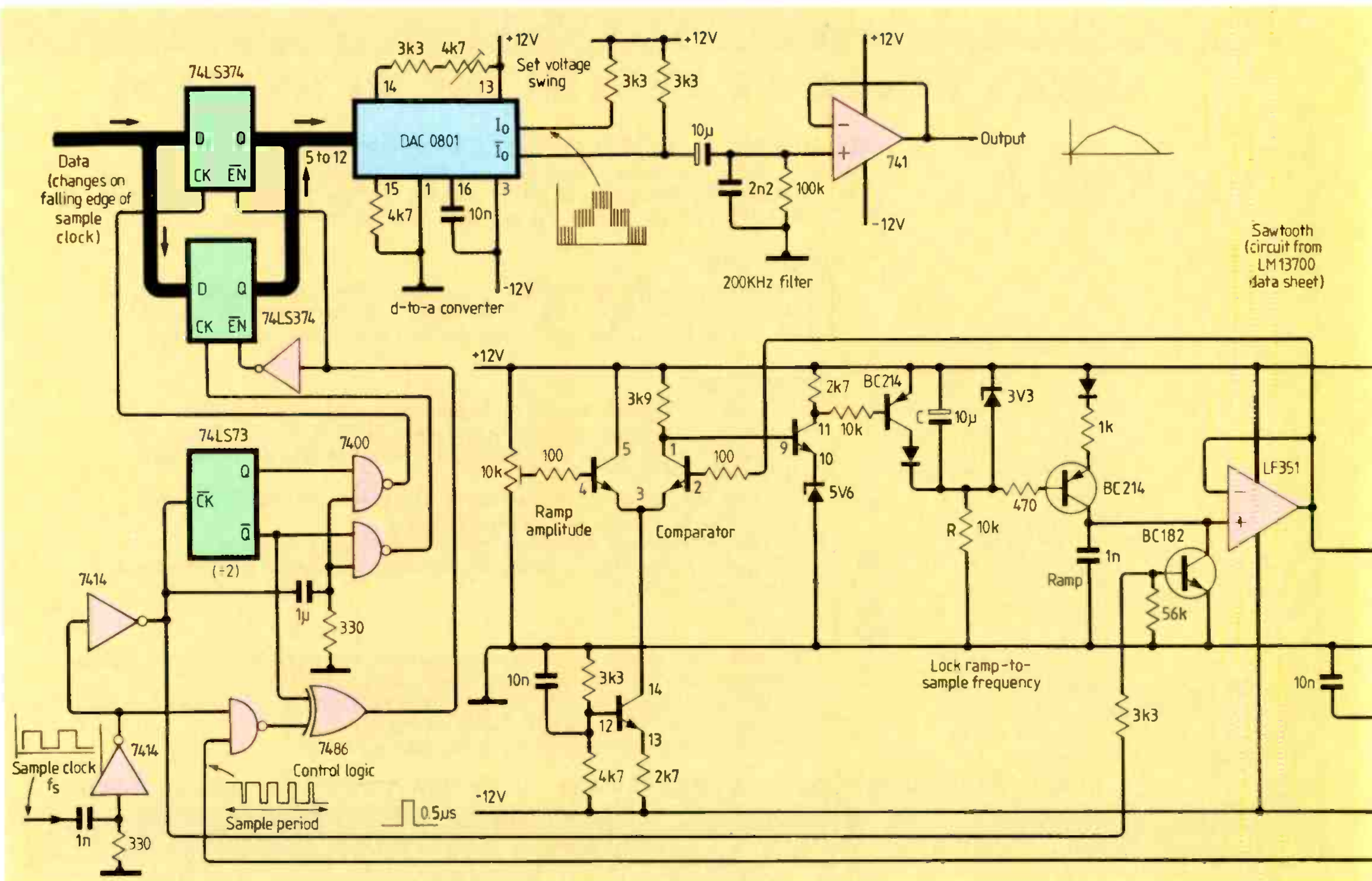


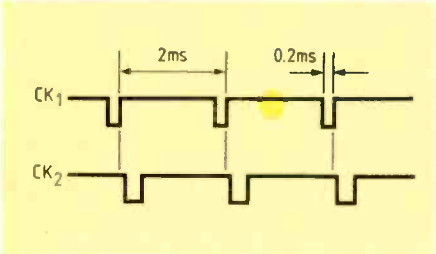
Automatic line matching using resistive couplers

Traditionally, a potentiometer and capacitor have been used to balance remote-sensor lines feeding amplifiers. Output of the amplifier is monitored on an oscilloscope and the potentiometer is adjusted for minimum amplified noise before the sensor is activated. Time is saved and the job is much simpler if the balancing is done automatically; this circuit balances at the push of a button.

Amplified noise, rectified and filtered, feeds two cascaded sample-and-hold amplifiers whose outputs are compared to monitor the noise level. Resistive opto-couplers





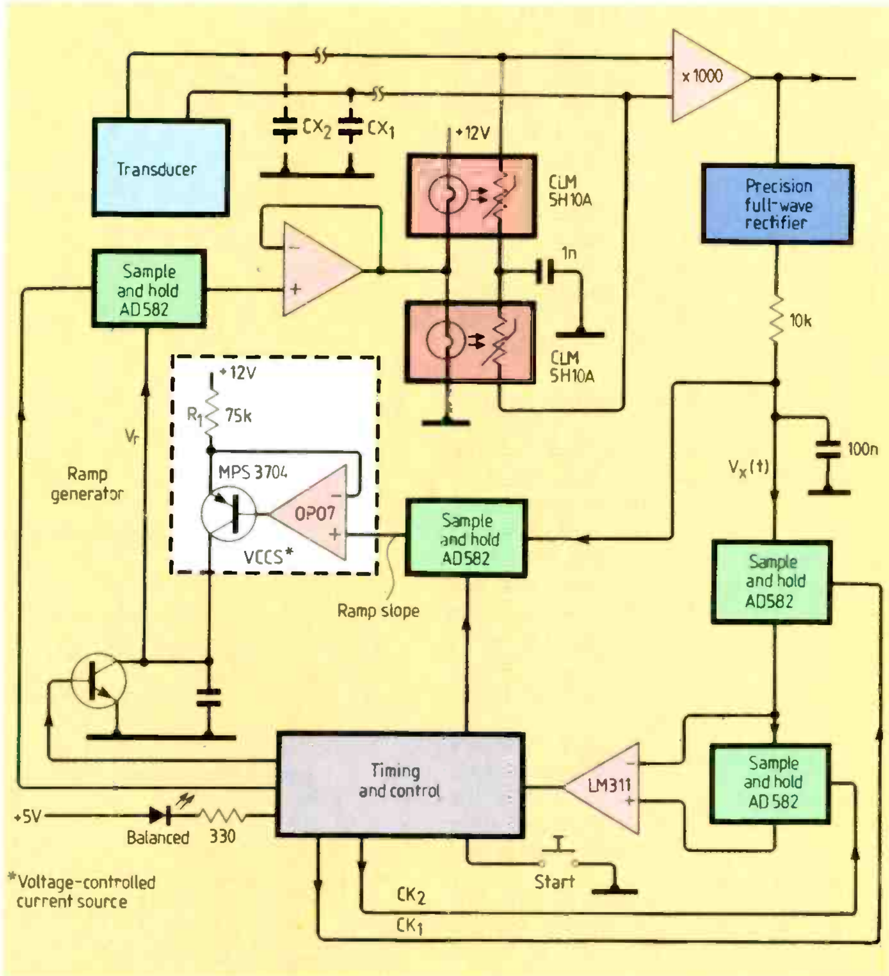


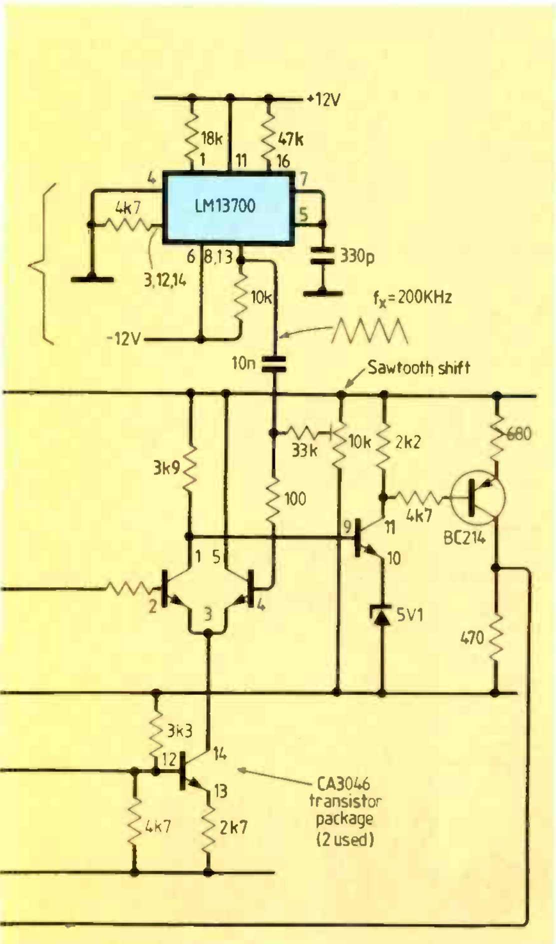
with a capacitor provide line impedance. This impedance is controlled by a ramp that is held when minimum noise is detected. A further sample-and-hold circuit samples the initial noise level and sets the ramp slope accordingly to compensate for noise-level variations.

Response time of the couplers is important; the Clairex devices used change from 1kΩ at 12V to 5kΩ at 6V in about 25ms. For accurate matching, the sampling period of the rectified noise should be 25ms/100 or better.

Replacing the instrumentation amplifier with an isolation amplifier such as the Burr-Brown ISO-100 will eliminate the need for batteries and make the circuit suitable for higher-voltage applications.

Davood Khalili
Santa Clara University
California





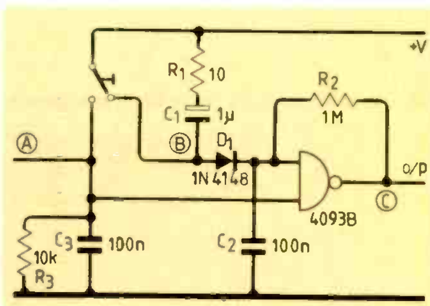
One-gate auto repeat with delay

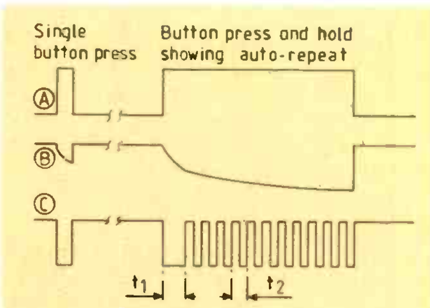
In simple digital systems, like a digital clock for example, push-buttons are used to make settings. An automatic-repeat circuit that produces a train of pulses if the push-button is held down makes operation easier.

Such a circuit can be made using just one gate — and it provides contact debouncing (C_3 and R_3). When the button is initially pressed, a single negative pulse is produced. After that, there is a delay determined by R_2 and C_1 until voltage at B falls below the gate's threshold. At this point the oscillator, consisting of R_2, C_2 and the Schmitt-trigger gate, is enabled.

When the key is released, output goes positive so the counter following the circuit should count on negative edges.

R.J. Eggleton
Huntingdon
Cambridgeshire





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CIRCUIT IDEAS

Dual-port memory

For interprocessor communication, dual-ported memory is efficient but dedicated dual-port i.cs are expensive. Provided that p.c.b. area is not at a premium, this circuit for interfacing two 68000 processors may be of use.

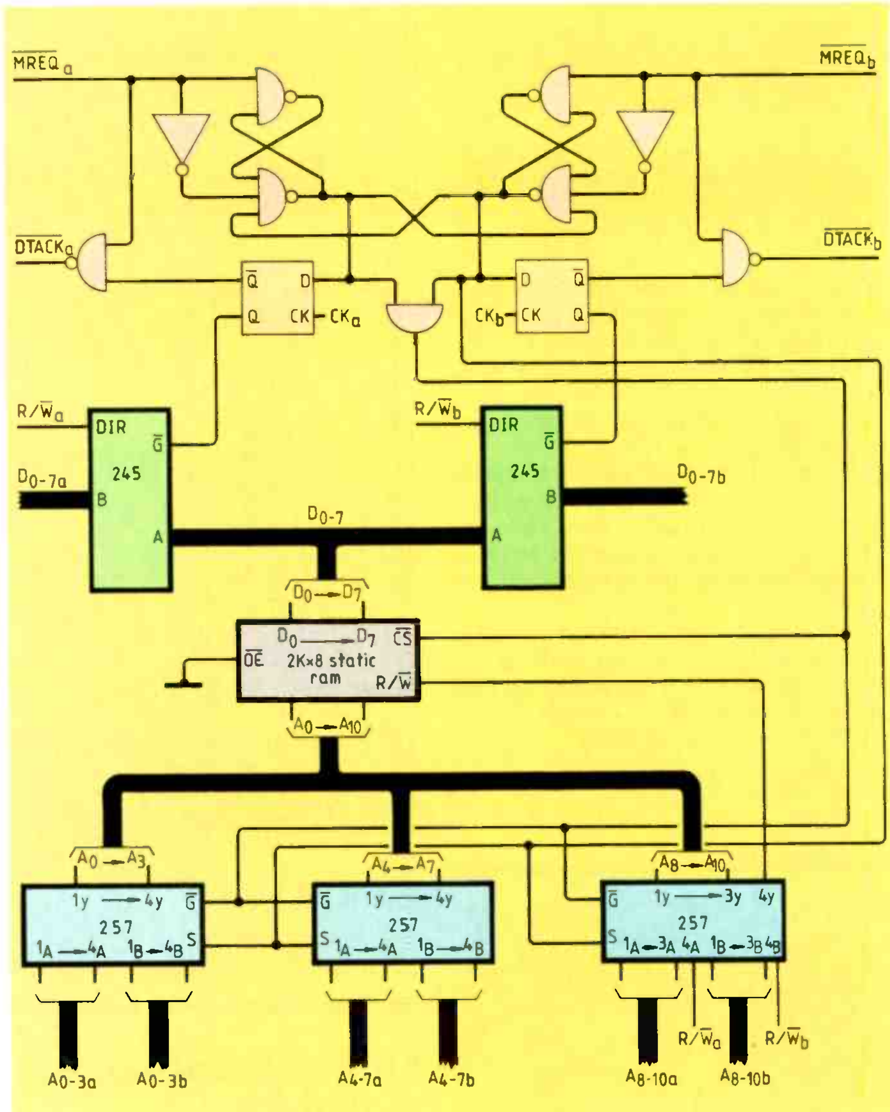
Two SR bistable devices at the top of the diagram arbitrate between the two processors. A memory-request signal from one processor sets the associated bistable device unless its counterpart has been set. When $\overline{\text{MREQ}}$ returns high, its associated bistable circuit is cleared.

Initially, $\overline{\text{MREQ}}$ is asserted and assuming that the requesting processor is allowed access, the multiplexer channel and the chip-select signals are activated. One clock cycle later, $\overline{\text{DTACK}}$ is asserted for that processor and the bus transceiver is enabled so that data can pass to or from the ram. After approximately one more clock cycle, the processor's address strobe rises and the arbitration logic changes state. The select signal to the multiplexers may change state but during the propagation delay, $\overline{\text{CS}}$ rises and the ram is disabled.

Clocks to the D-type bistable devices should run at half those of the processors. Since $\overline{\text{MREQ}}$ is the select signal for the memory banks, it should be produced using the address strobe and not just upper and lower data strobes.

Open-collector gates are used for the $\overline{\text{DTACK}}$ signals but three-state outputs could be used, with $\overline{\text{MREQ}}$ acting as the enable signal. Adding a multiplexer would provide four more address lines, allowing 16 times more memory to be addressed.

Richard Walker
Alfreton
Derby



NEXT MONTH

Industry Insight. Semiconductors are the subject of the third of our new series of commentaries on selected areas in the electronics industry.

Multiprocessor systems. First of a series on linking 68000 processors provides an overview of multiprocessor systems and considers some interprocessor topologies. Subsequent articles will discuss shared-memory processing and multiprocessing on the VMEbus.

Programmable logic devices. Software has been developed to make programming p.l.ds much easier. As an example, an alarm system is used to demonstrate the practical development of an application-specific i.c. using p.l.ds.

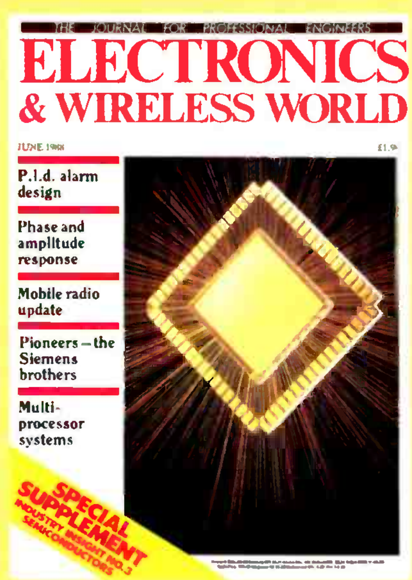
Pioneers 18: The Siemens brothers, founders of an electrical empire.

Mobile radio – progress with pan-European cellular radio and news of other technical developments from the Mobile Radio Users' Association conference at Cambridge.

In Research Notes – John Wilson reports from Moscow on Soviet progress with projection receivers for high-definition tv using solid state lasers.

Phase from amplitude. Development of the numerical procedures for deriving phase from amplitude, and vice versa. Examples are used to illustrate the effectiveness of the procedures described.

Reversing constant current in an inductor. Reversing a 'constant' direct current through a coil is problematical. David Griffiths takes a down-to-earth look at the problems and offers a guide to some of the oddities.



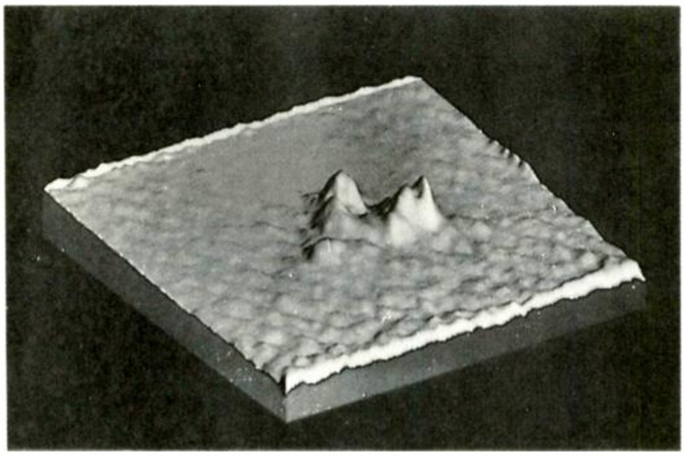
RESEARCH NOTES

Building with atoms

Physicists at IBM's Almaden Research Center in California have recently achieved what they describe (*Nature* vol.331 no 6154) as "the smallest yet, purposeful, spatially localized changes in matter". In everyday language they've succeeded in shifting individual molecules to and from a polished graphite surface using a scanning tunnelling microscope (s.t.m.)

The s.t.m. is a tool originally invented over ten years ago by IBM scientists to probe the surfaces of matter. In essence it consists of nothing more than a fine needle suspended about ten atoms' diameter above the surface to be investigated. The exact height is measured by detecting the tunnelling current that flows between the two when a potential is applied. It's exactly the same principle that lies behind the operation of a tunnel diode, except that in this case the insulator across which the electrons tunnel is air. If, as in the s.t.m. the needle is servo-controlled to maintain a fixed distance from the surface over which it is suspended, and is then made to travel laterally across the surface, a readout of the loop control voltage will provide a much-magnified picture of that surface. Repeating this operation in several different directions eventually allows the operator to build up a picture of the surface so detailed that it will show individual atoms.

What the IBM researchers have now done is to use the s.t.m. not just to observe but to manipulate. Instead of just having air between the fine needle and the graphite surface, they placed a drop of a chemical known as di (2-ethylhexyl) phthalate. This is just one of many organic chemicals that seem to produce good results. At normal bias levels of around 30mV the liquid behaved just like air and allowed the s.t.m. to produce an image of the graphite underneath. But when a pulse of 3.7V was applied, one molecule of the organic chemical attached itself to the graphite substrate (as revealed by a subsequent scan at the low bias voltage). The picture shows an electronically synthesized three-dimensional view of the single molecule sitting on the graphite surface.



The fact that atoms, or groups of atoms, can be deposited in this way has been known before: what hasn't been done before is to reverse the process and wipe the slate clean. To do this the IBM team cause the needle to pass over the deposited molecule and pass another pulse of around 3.7V. In some cases the entire molecule disappears; in others there is what they term "partial erasure". What that obviously means in chemical terms is that the organic molecule has been cleaved in two.

To perform this 'writing' or 'erasure' operation, the group found that they needed to exceed a certain threshold voltage – approximately 3.5V. This, they believe, corresponds to the energy which the tunnelling electrons need in order to activate the absorbed molecule – coincidentally the energy of a typical single carbon-to-carbon chemical bond.

Clearly, as the IBM team admit, there is more theoretical work to be done in order to understand precisely what is going on at the atomic scale. Nevertheless they believe they are on the threshold of what they describe as a "revolution in manipulating atoms and molecules for a variety of purposes". Such purposes very obviously include the creation of electronic devices on a scale hitherto undreamt of. They also include the possibility of the ultimate memory device in which a single bit of data is registered as the presence or absence of a single atom.

Mood indigo

The extent to which the English language is being debased is a theme guaranteed to raise the blood pressure of many a pedant, not least in the world of electronics. Popular use of terms such as 'video' and 'stereo' seems set to strip the discipline of any remaining adjectives. But before becoming too incensed at the misuse of English we might ponder on some of the less objectionable changes. In my dictionary the word 'pink' is defined as a pale shade of red, yet to engineers it may imply a type of noise – coloured noise. Other adjectives such as 'loud', 'bright' and 'dull' apply equally well to sight or sound.

This cross fertilization of terminology may at first sight (or first hearing) seem purely accidental, though there's plenty of evidence to the contrary. Long before the advent of hi-fi, composers were very ready to attribute colours to the various musical keys, though attempts to relate colour to tone quality are dismissed rather scornfully by the Collins Music Encyclopaedia as being 'based on pure fantasy'. But are they?

Wharfedale's sales and marketing director Walter Mirauer tells me that the visual colour of a loudspeaker really does make a difference to the way it sounds. Experiments were conducted with over 300 students at Sandwell College of Further Education in Birmingham to provide – for the first time – really good statistical evidence. What the experimenters did was to take a number of identical Wharfedale speakers and fit grilles of different colours. As explained to the students, the different colours were purely for purposes of identification. Subjects were then allowed to switch between the various speakers and asked to note the differences.

Reported differences proved highly consistent, even if the grilles and the speakers were interchanged. Any speaker with a red grille appeared (sorry: *sounded*) more bassy; yellow speakers, by contrast, were perceived to be louder than others; blue ones seemed clearer.

One amusing outcome of these experiments was the finding that black or brown speakers beloved of the audio trade were regarded as dull and lifeless. Mirauer believes that the subjective effect of a loudspeaker's colour is much more significant than many of the subtle (though in his opinion, less important) factors that are currently attracting the attention of hi-fi cognoscenti.

Wharfedale's philosophy of 'horses for courses' now extends beyond just marketing speakers in ten different grille colours. In conjunction with Sandwell College they are now researching other factors that may change the way we perceive sound, such as our degree of inebriation. Anecdotal evidence suggests that alcohol reduces the amount of bass we hear. Could that explain why so many speakers get blown up at parties or why a couple of pints does wonders for my organ playing?

If these changes in our perception can be quantified precisely, then they can – Mirauer believes – be compensated for in the design of speakers for particular applications, such as juke boxes. Or, if speakers are suitably rated, and of course painted red, the correction could be performed at the amplifier. He foresees specialist amplifiers of the future incorporating a 'booze' button in place of the 'loudness' control!

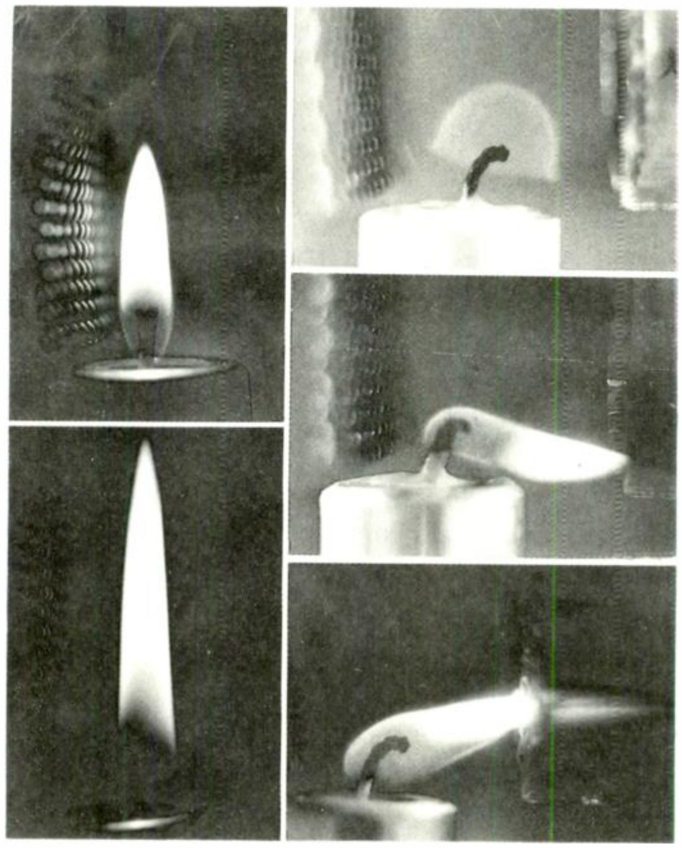
Gamma rays and v.l.f. propagation

Researchers at the NASA Marshall Space Flight Center and at Stanford University report what they believe to be the first event outside the solar system that has measurably affected a part of the Earth's environment (*Nature* vol.331 no 6155). The event in question was a gamma ray burst originating somewhere in the constallation of Leo and what it did down here was to cause a massive hiccup in the propagation of v.l.f. radio waves around the world.

Simultaneous measurements made in Hawaii, Maryland and Antarctica all showed a pronounced change in amplitude of the signals originating from the 16kHz GBR transmitter at Rugby. Gamma ray bursts don't penetrate right down to the Earth's surface, but their implication in this v.l.f. disturbance was confirmed by observations made by three separate satellites, ICE, Prognoz-9 and Vela.

Propagation at v.l.f., which depends on the lower ionosphere behaving as a sort of giant waveguide around the Earth, has been used as a sensitive measure of many other atmospheric disturbances. X-rays and microwave emission from solar flares can readily be detected by their characteristic effects on v.l.f. reception. 'Whistlers' (see Research Notes, *E&WW* September 1987) are also observable in this way.

In their latest paper the NASA and Stanford physicists say that the use of multipole v.l.f receiving stations may in future enable extraterrestrial gamma ray sources to be located and measured with a much greater degree of accuracy than is currently possible by observing them directly from spacecraft. It might also be a lot cheaper!



Candle flame with varying gravity and field strength. Clockwise from bottom left: 2g, zero field; 1g, zero field; zero g, zero field; zero g, increasing field strength; same. By courtesy of *Nature*.

How to light up in space

What happens to flames in weightless conditions? Before reading on, give it some thought! The answer, at least where an ordinary candle is concerned, is that convection currents virtually cease and the flame becomes a feeble spherical blob that eventually extinguishes itself. When gravity is removed, the air flow around a flame stops and combustion products accumulate in the form of a halo. In practice that means that ordinary flames can't be used in spacecraft without the provision of jets of compressed gas to create artificial convection currents.

A simpler and lighter method of firing up an extra-terrestrial candle is described in a recent paper by Professor Felix Weinberg and his co-worker Dr F.B. Carleton at Imperial College, London (*Nature* vol. 330 no 6149). It makes use of the fact that flames consist of highly ionized gas particles that respond to the pull of an electric charge. So instead of relying on convection currents to shape a flame, Weinberg and Carleton use an e.h.t. generator of the sort used to power electrostatic crop sprayers. Not only can the flame shape be controlled, it can also be precisely directed on to any surface that needs to be heated.

Practical tests were sponsored by the European Space Agency and undertaken in an aircraft provided by NASA. By flying in a parabolic path it is possible to simulate weightlessness for periods of up to 30 seconds at a time. Test results show that for the expenditure of very modest amounts of electricity (less than $0.1Wcm^{-2}$ of flame), it is possible to provide tightly focussed flames with simple lightweight equipment. This means efficient use of fuel and minimal consumption of oxygen from the environment. It also opens up new possibilities here on earth for re-shaping or re-directing flames in awkward environments or where natural convection can't be relied on.

Cheap active l.c.ds on the way

The development of cheap, high-performance liquid-crystal displays depends first and foremost on chemistry. But however fast and thermally stable a display is it still needs every picture element to be individually addressable. That of course is not real limitation for watches and calculators where each element is large. The problem comes in applications such as television sets where an individual picture element must be as small as possible.

Obviously one answer would be to have a lead-out wire for each row and column and to address the picture elements by means of external electronics. The prospect of connecting up about 1500 lead-out wires for a 625-line screen does however raise practical difficulties.

The logical solution of course is to integrate the drive circuitry with the display, though this poses problems of its own. Until now the choice has lain between using glass as the common substrate and creating transistors from films of polysilicon. The first solution is cheap but has severe performance limitations; the latter works well but is extremely expensive.

A way out of this dilemma is now in prospect, thanks to work being funded by the General Motors research laboratories in Warren, Michigan. Research student Leland Spangler, working for his doctorate at the University of Michigan, has succeeded in creating transistors on a glass substrate that have electron mobilities greater than anything hitherto deposited on glass. They are in fact comparable in performance to transistors made from bulk silicon.

The process, which at first sight appears back-to-front, starts with a silicon substrate on which an epitaxial layer is deposited, followed by a dielectric. The dielectric layer is finally bonded to the glass, after which the silicon is thinned and etched.

Vital to the whole process is a special glass which will stand the high processing temperatures.

Television sets and portable v.d.u. screens are two obvious applications for cheaper high-performance active matrix liquid crystal displays. General Motors, predictably, also has in mind the applications of this silicon-on-insulator technology to reconfigurable dashboard displays. That, in layman's language, presumably means that when you pull off the freeway you can watch Dallas on the gas gauge.

Research Notes is written by John Wilson of the BBC External Services science unit at Bush House.

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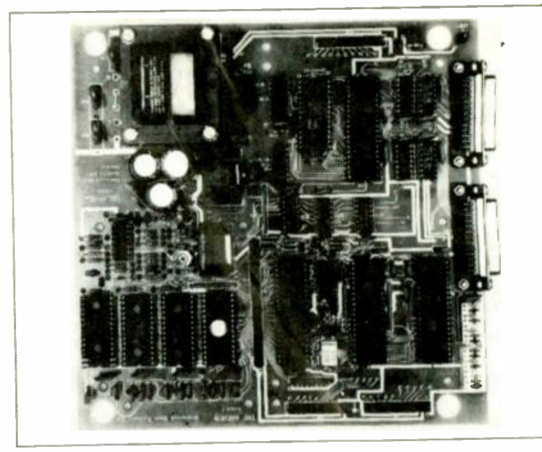

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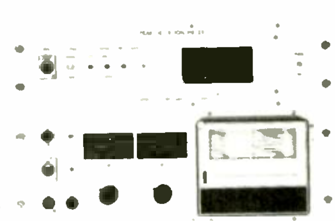

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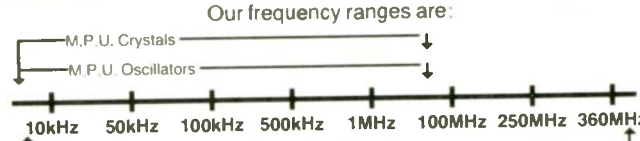

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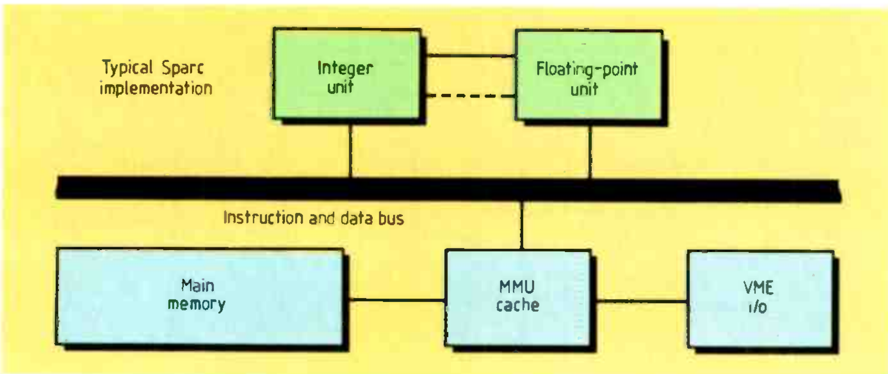
APPLICATIONS SUMMARY



Risc tutorial

Reduced instruction set computer architecture can be thought of as a delayed reaction to the evolution from assembly language to high-level language. Assembly language programs use a microprocessor's elaborate instructions but compilers do not.

These statements, from a short risc tutorial from Sun Microsystems, are supported by the claim that the company's C compiler only uses about 30% of the 68020's instruction set. Sun says that approximately 80% of the computations for a typical program require only about 20% of a processor's instruction set.

Simpler microprocessors result from this philosophy; Sun's Sparc risc processor for example has only 50 000 transistors whereas the 68020 has 200 000. One of the main differences between risc designs and traditional architectures is the replacement of microcode with hard-wired logic. Microcode adds complexity and raises the number of cycles per instruction. Most risc instructions are executed in one cycle.

Other differences between risc and traditional microprocessor architectures are described in the tutorial, together with details of the Sparc risc processors and a history of risc.

Peak-detecting data acquisition for processor interfacing

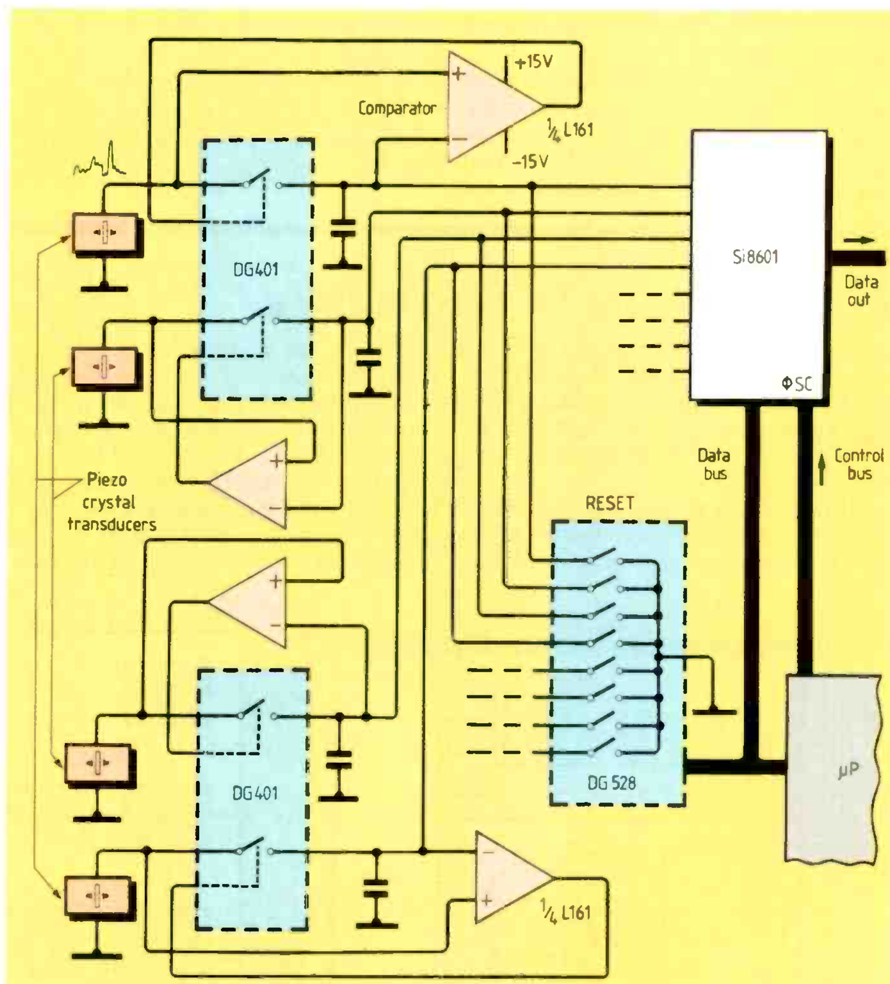
In data-acquisition applications where peak amplitude sensing is of primary importance, comparators and analogue switches connected as shown ensure that high peaks of short duration are not missed even though the sampling rate may be much slower than the peak duration.

An L161 low-power comparator drives the 401 switch control inputs to detect and hold peaks. When input on any channel is higher than the level on its associated hold capacitor, the comparator turns the input switch on and the input level is held on the capacitor ready for reading. After the reading is sampled the capacitor is discharged through a further switch i.c. ready for the next detection.

The design is primarily for reading peaks from piezoelectric vibration sensors and, consuming around 2mA in its quiescent state, it is suitable for use in portable equipment. At the heart of the system is an Si8601 data acquisition i.c. providing eight-bit conversion. This device has an eight channel analogue multiplexer that sequentially interrogates each vibration sensor in turn.

Analogue input information is converted to an 8bit digital word for processing by a microprocessor, or used in conjunction with a display driver to deliver a visual readout.

Conversion time of the circuit is 25μs, at 175μs intervals. Other notes in the Siliconix applications leaflet include a high efficiency switch-mode regulator, a programmable current source and sink and a switched attenuator.



ADDRESSES

Siliconix
3 London Road
Newbury,
Berks RG13 1JL
0635 30905

Sun Microsystems Europe
Sun House
31 Pembroke Broadway
Camberley,
Surrey GU15 3XD
0276 62111

SenSym
Hi-Tek Electronics
Ditton Walk
Cambridge CB5 8QD
0223 213333

Analog Devices
Station Avenue
Walton-on-Thames
Surrey KT12 1PF
0923 232222

Tank-level limit monitor for battery operation

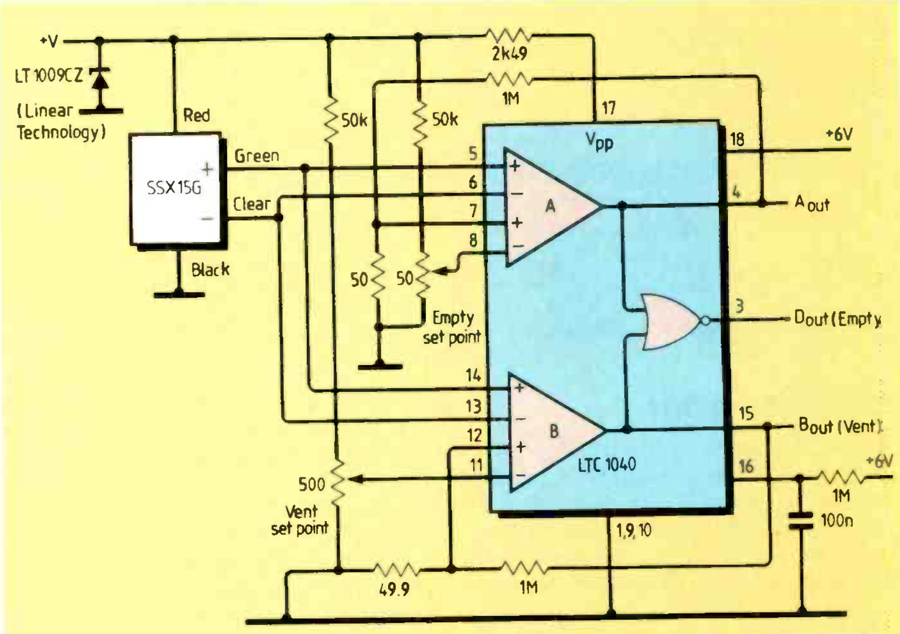
Electronic circuits for constantly monitoring the level of liquid in a remote tank should have low power consumption if battery power is to be used. This low and high-level limit monitor is suitable for battery operation. It has two main components – a SenSym SSX pressure sensor requiring around 625μA with a 2.5V supply, and an LTC1040 low-power comparator configured as a window detector.

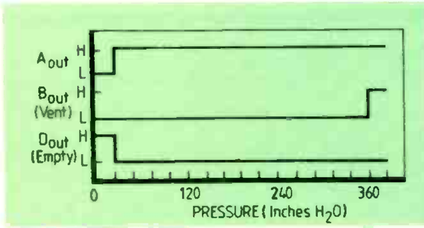
Any liquid compatible with stainless steel can be measured by the SSX sensor, and its pressure limit is a water column of 10.67m. In this example, the upper and lower-level limits are 9.144 and 0.61m water columns respectively.

At the 'empty' limit of 0.61m and a sensor supply of 2.5V, sensor output is 1.08mV; the 'empty' potentiometer allows a 0 to 2.5mV adjustment. For the upper limit switching point the pressure sensor outputs 16.3mV; the 'vent' potentiometer has an adjustment range of 0 to 25mV.

To set up the circuit, apply a 610mm water column and adjust the 'empty' potentiometer to the point where A_{out} changes from low to high. Apply a 9.144m water column and adjust the 'vent' potentiometer to the point where B_{out} changes from low to high. Repeat these steps as necessary until the desired accuracy is achieved.

SenSym application note SSAN31 also contains a simpler low-power pressure switch and discusses the circuit's use as an air-filter monitor that senses the increase in vacuum at one side of a fan when the air filter becomes clogged.





Analogue i/o for PC compatibles

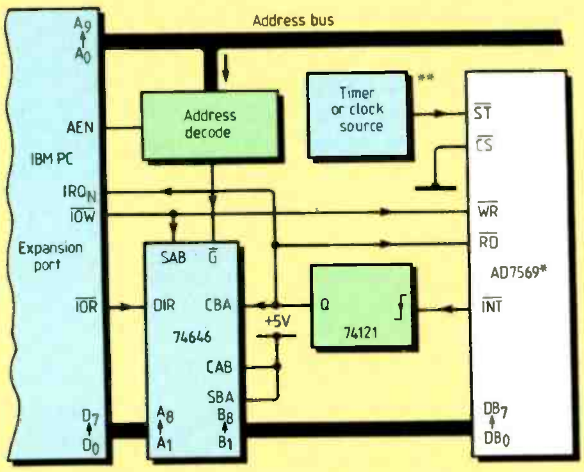
Having microprocessor interface logic, an a-to-d converter, a d-to-a converter and a reference in one i.c. greatly simplifies analogue i/o circuit design. This eight-bit analogue i/o port is designed for interfacing with PC compatibles.

Analogue-to-digital conversions are initiated using a precise clock to provide equidistant sampling intervals. At the end of the conversion, the interrupt line goes low and the 74121 monostable i.c. produces a read pulse for the 7569. This read pulse accesses data from the converter and places it into a register in the 74646.

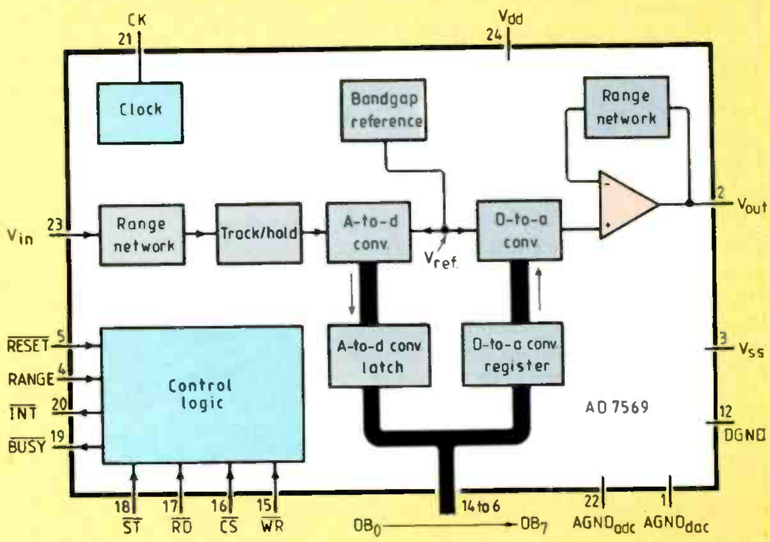
An interrupt request to the processor is produced at the rising edge of the read pulse and the conversion result is read from the 74646 register by the processor using an input/output read operation.

An i/o write operation by the processor transfers data to the d-to-a converter through the 74646 register. Data is latched into the d-to-a converter on the rising edge of $\overline{IOW}$.

Other examples in the AD7569 data and applications leaflet show how the device can be interfaced to Z80 and 68008 microprocessors and the ADSP2100 digital signal processor.



*Additional circuitry omitted for clarity
**For precise sampling applications



FEEDBACK

Frequency changes

The item headed 'Droitwich frequency shift' in the December, 1987 Update column contains some information which is incorrect.

The Droitwich long wave transmission is, has long been, and after the frequency change will continue to be, continuous 24 hours per day. Whether or not the programme is called 'Radio 4' for the whole of the transmission time is immaterial if the interest is only in the carrier!

The range is substantially greater than 300 miles. I have used the Droitwich transmission at ranges well in excess of 500 nautical miles and have obtained consistently good results.

The Droitwich transmitter is controlled by a rubidium standard and its phase offset is measured by the NPL with reference to UTC (NPL) which is derived from a caesium standard.

As a matter of interest, the availability of the Droitwich transmission is much better than that of the 60 kHz MSF transmission. The Droitwich transmitter has been off the air this year for the first time in my recent experience.

I have several off-air frequency standards tuned to the Droitwich transmission. The more recent ones can be changed to 198 kHz by retuning the aerial, changing a filter crystal, and moving a wire link. Even the older ones can be modified to give a phase-locked output, albeit at a slightly less useful frequency than the standard 10 MHz output frequency. A *WW* article (January 1981) describes a method of conversion to provide a 200 kHz signal, which should be adaptable to most of the older off-air frequency standards.

J.R. Tilsley
New Malden
Surrey

I am among the British citizens living on the Continent of Europe, down in S.W. France some 500 miles due south of London and on fairly high ground.

Prior to 1st February we received BBC4 200 kHz loud and clear most of the time. Now our signal has a loud and continuous 2 kHz whistle whatever the aerial system used.

We were told the change to 198 kHz was part of a worldwide agreement to regularise the 9 kHz separation in the interests of mutual interference (although why it could not have centred on the very useful 200 kHz frequency I cannot imagine). I know it is argued that we folk choosing to live outside the UK have no right to complain, but it should be pointed out that most of us still pay UK income tax!

On the more technical side, the 200 kHz signal would fade occasionally, generally around dawn and sunset. Then we were aware there were several other stations on the same frequency, or so close as to produce no audible beat. All we ever got was a low-level jumble. Now we are never free from the 2kHz whistle and 2 kHz is in the most sensitive part of the ear's frequency range. The directional properties of transistor ferrite aerials don't help at all, even though one can find two good nulls for BBC4, i.e. showing these simple aerials really have figure-of-eight directional properties. This, again, suggests several transmitters in different directions. My 200m Beverage aerial is very slightly better as I suppose there are no unwanted transmitters due north.

I think the whistle is slightly less powerful now than it was during the first week of February and it now often has a slight tremor. This suggests that one of these transmissions has changed to 198 kHz and the remaining 200 kHz signals wander relatively a few Hertz.

As this interference is mutual, surely we shall be receiving complaints from other countries as long-wave signals can travel great distances in favourable conditions, so I await with interest the next few issues of *EWW* and Pat Hawkers' comments.

On the score of sound quality, we have always looked down on long-wave reception due to bandwidth problems; in fact, for twelve years we have been using the tone control to give some top lift to make speech clearer as news bulletins are our most important listening. A few months ago we bought ourselves a modern synthesizer receiver with a superior detection system. A revelation: BBC4 long wave is really very good sound quality. We now need no help from the tone controls and yet we get no trace of adjacent channel interference despite powerful French transmissions.

Here in France we have excellent sound quality, of course, from a variety of f.m. stations, but it is (was) very gratifying to get comparable quality from the UK.

We can, of course, receive short-wave transmission but the continual fading makes such signals only worthwhile when the long waves are drowned in static from extensive local thunderstorms.

Ralph West
Villereal
France.

Quality in a.m. radio

My attention has been drawn to an contribution by R. Kearsley-Brown, in the February, 1988 issue of *Electronics and Wireless World* in which he makes substantial criticisms of an earlier article of mine; the title of which, incidentally, was not of my choosing: published in 'EWW' in October, 1986.

In the first part of my article, I endeavoured to summarize the design techniques available for the implementation of 'bandpass-coupled' pairs of tuned circuits, which were examined comprehensively by B. Sandel in Chapter 26 of the Radio Designers Handbook (4th Edition, 1954), and to suggest a way in which currently available and inexpensive i.f. transformers might be used more advantageously in this type of circuit.

The measured bandwidth of a single bandpass-coupled i.f. stage constructed with these coils was 12kHz at the −6dB points, and reference to the 'universal selectivity curves' published in Chapter 9 of the same reference manual suggested a working Q value of about 100 for these coils.

Reference to the rather more precise selectivity curves shown in the Wireless World Radio Data Chart, No 19, and reprinted by Mr Kearsley-Brown, suggests that the actual working Q value of the coils which I had used was probably nearer to 70 than the value I had supposed, and that the value for the coupling capacitor should therefore be increased from 10pF to 15pF. However, this seems to me to be a relatively small molehill of technical error for Mr Kearsley-Brown to construct such a mountain of criticism.

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

Pie Tea

Joules Watt's "weird title" In your January 1988 issue owes at least a little to my "Pie Tea" in *WW* October 1956. But my article, like its title, was slightly briefer, not having been written exclusively for 'professional engineers'.

A thought occurs to me: did J.W. read *WW* in 1956?

"Cathode Ray"

Multiple-output power supplies

The article "Multiple-output power supplies" in the March issue raises a little considered piece of poor engineering practice. The article describes a supply in which the power i.c. employed contains the series switch, voltage control amplifier and the overvoltage protection circuit. If the latter function is required and is to be worth paying for, then it must be totally independent of the converter itself, since a major failure on the chip is likely to disable the protection at the same time.

It is not necessary to look hard for an example: the French telecommunications satellite Telecom 1B is presently tumbling gently out of orbit following loss of a solar-array drive. The suspected cause is an overvoltage failure in a d.c.-a.c. converter which propagated to the standby converter, located in the same box, causing complete loss of the equipment despite the expensive efforts that had been made to design a fault-tolerant system.

R. McGregor
Hitchin
Hertfordshire

Radio communication through rock

This article gave a very useful review of the state of the art in this field. I was, however, disappointed to see that it perpetuated the fallacy that equipments of this type operate by virtue of electromagnetic/wave propagation (EM).

A multiturn coil of wire, resonant or not, does not radiate any significant amount of electromagnetic energy. Such energy is only radiated from a loop in the special case when it is of only one turn. If the peripheral length is one wavelength the loop is then self resonant and behaves very similarly to a folded dipole, from which it is derived. Smaller, single-turn loops will radiate, but the radiation resistance falls so dramatically that they are ineffective when their lengths are less than one tenth wavelength. Folding a single turn to form a multiturn coil destroys the phase and spatial relationship between the magnetic and electrical components of the generated fields. For radiation of electromagnetic energy both an electrostatic and an electromagnetic field, mutually at right angles and in phase, must be produced by the antenna. The resulting wave then propagates along the third axis.

It is for this reason that portable equipments of this type, using very low frequencies, will only function over a few hundreds of metres, even in air. They operate by virtue of simple magnetic induction as perceived by Faraday and Helmholtz. The relation between field strength and distance from the transmitting coil is now an inverse cube law.

In trials, the results from which are supported by calculation, I have found that a multiturn coil of one metre diameter with ten amps drive and with receiver sensitivities of one microvolt, a range of 700 to 1000 metres in air is about the limit.

With regard to penetration of radio frequency energy into the ground. Where investigators have used broadcast transmitters many kilometres from the site they are clearly dealing with EM radio waves, but where the experimenter has used his own transmitting antennas it is not often clear which field is predominant, the "near field" or the true EM field. The former can easily mask the latter at short distances.

I am not at all happy to accept that penetration versus frequency curves applicable to EM energy are appropriate to near-field investigations. The limitation on the penetration of an EM radio wave is said to be more dependent on the electrostatic component than the electromagnetic one so I think it dangerous to assume that an alternating magnetic field will suffer the same attenuation as a wave of EM radiation.

Multiturn coils, nowadays using ferrite-rod cores, are used for the antennas of most medium and long wave broadcast receivers. It is fortuitous that while an antenna capable of producing both components of the EM wave is essential for the generation of same, only one component is necessary at the receiver since the information is duplicated in the two fields. For a coil the magnetic component is used, but it must be orientated correctly for optimum performance and it is interesting to consider this with respect to the two types of energy transfer under discussion, viz. EM radiation and magnetic fields.

A transmitting station using a single turn full wavelength loop (the QUAD antenna) will produce a "near field" generated by currents unrelated to the standing wave currents in the resonant loop and also radiate energy as a result of the latter. The flux associated with this field will be aligned along the axis of the coil and a small multiturn receiving coil will require its axis to be similarly aligned for maximum induced signal.

If we move away so that the near field is absent we are now able to detect the magnetic component of the EM radiation and it will be found that the signal maximum now occurs with the plane of the receiver's coil on the axis of the coil of the transmitter. Clearly this magnetic flux is at right angles to that previously observed. This provides a useful way of establishing which magnetic field we are looking at.

The much greater ranges sometimes achieved are explained by the fact that the transmitter multiturn coil is inducing a voltage in a nearby electrical conductor. If this latter is insulated and conveniently connected electrically to ground at each end then the circulating current which results will create a magnetic field which will be detectable in the vicinity of the conductor, which could be many kilometres long. If the conductor is natural or is not connected at its ends then the capacitance to strata along its length will serve to provide a loop, though the shunting effect will reduce the range considerably.

There are situations where ranges of exceptional distance are reliably achieved. Two known examples are where the associated secondary conductor is of a resonant length for the frequency in use and consequently becomes a true EM transmitting antenna in its own right. The other is where natural geological conditions, perhaps together with lattice resonance effects in the materials from which the rock is formed, form a guide.

The author has obtained clear communication on 27MHz through a hundred or so metres of strata using only whip antennas, so magnetic induction was minimal. This was explained by the presence of vertical "rakes" of lead-bearing ore in the vicinity of both stations. Reception ceased when either station moved a short distance from the optimum position.

Far more work has been carried out than is implied in the article, mainly in the USA in connection with speleology, the science of caves, but the journals in which it was published are not widely circulated. The author can make claim to reliable two-way speech communication through a hundred or so metres of limestone in 1962[1] and over a thousand in 1967[2]. The system used the lowest frequency possible, the speech frequencies themselves. Modern techniques using a carrier permit much higher receiver sensitivies and a combination of this and single-sideband modulation provides for lower noise and minimal power wastage.

References

1. Proc. British Speleological Conf. 1963.
2. Manual of Caving Techniques. Routledge & Kegan Paul, 1969.

Harold Lord
Bakewell
Derbyshire

Coupling coefficient

We thank Mr Chadney (February letters) for his interest in the article in the June 1987 issue and for drawing our attention to the textbook by Page and Adams, of which we were not previously

FEEDBACK

aware. We have consulted the pages cited by Mr Chadney, and consider the material there in no way weakens the tentative claim to the originality of the r.f. link described in the article.

Page and Adams consider two cases of a pair of inductively-coupled serious-resonant circuits in forced continuous oscillation. In the first, the tuning of the circuits is constant, the coupling coefficient is a parameter and the frequency is the independent variable. The authors show the usual single- or double-humped curves for primary and secondary current, depending on whether the coupling is below or above critical.

In the second case, the frequency is fixed, couping coefficient is the independent variable, and it is supposed that, as the coupling coefficient varies, somebody keeps the tuning adjusted so that both circuits remain resonant. It is then found that the secondary current rises with coupling coefficient until the latter reaches a critical value, after which the current remains constant. This behaviour is similar to that exhibited by the MRC link, but the two systems are quite different. The arrangement described in the June 1987 article represents a third case, in which coupling coefficient is the independent variable, the tuning is fixed, and the frequency adjusts itself automatically – over the stabilising range – to achieve constant secondary current.

This third case is not considered explicitly by Page and Adams, nor is its useful behaviour obviously implicit in the cases they do consider: if it were, they would surely have mentioned it.

If it should turn out that the MRC distance-insensitive link has not in fact been reported before, we offer two possible reasons for this:

1. Much of the theoretical work on such systems was done by radio men at a time when economy in the use of the spectrum was becoming essential. A system in which the carrier frequency wandered about would be anathema.

2. Much of the theoretical work on such systems was done when the valve reigned supreme, and valves went naturally with shunt-resonant circuits. Writers were inclined to use series-resonant configurations only as a stepping-stone to shunt circuits, because the analysis was simpler. You couldn't make an efficient series-resonant oscillator using valves, so there wasn't much point in dwelling upon what such an oscillator would do.

P.E.K. Donaldson
MRC Neurological Prosthesis Unit
London SE5

T.E. Ivall
Staines
Middlesex

Relativity

Having been assured by Dr C.F. Coleman (Letters, March 1987) that I am now bereft of my sense of weight discrimination I invite him to yet further my education and also that of your readers by telling us how to calculate the angular momentum of the top as it moves round the tower?

Alex Jones
Swanage
Dorset

The letter by J.C.G. Field (*EWW*, March 1988, p.243) will hearten those who find the Einstein debate is becoming rather tedious, besides being unwarranted. His message is that we should not need 'proof' of the kind demanded by philosophers; it is sufficient to know that Einstein's theory works and is used by engineers.

I submit that if an engineer (and I am one myself) thinks that Einstein's theory is used in designing apparatus in which an electron's mass tends to become infinite as the speed of light is approached, then he has missed the point of Dr Essen's criticism (*EWW*, February 1988, p. 126). Classical electromagnetic theory explains why energy has a mass property and why the mass of a particle increases progressively as its kinetic energy escalates with both speed and mass. J.J. Thomson did not need to know anything about Einstein's 20th century theory when, in the 19th century, he designed cathode ray tubes and studied why the electron mass becomes infinite at the speed of light.

However, the reference to NAVSTAR is much more relevant. If engineers really have found it necessary to adjust for time dilation to allow for a loss of 350 nanoseconds per hour and avoid a build-up of positional error of 100 metres per hour, then that makes nonsense of the philosophical discussions. It is time that the 'engineering' details involved were published to clear up the misunderstandings. The weaker gravitational effect on atomic clock rates certainly can be dismissed as irrelevant to Einstein's hypothesis. It is worth reading Leon Brillouin's book 'Relativity Reexamined' (Academic Press, 1970) to see why. Einstein would have us believe that a photon or EM wave changes frequency as it passes through a gravitational field, whereas a quantum physicist should prefer the gravitational effect to have something to do with the potential of the energy quantum in the atom that determines the photon frequency. An engineer might be satisfied with Einstein's formula, because it works, but that does not mean that the underlying abstract hypothesis used by Einstein is valid.

So, we are left with Dr Essen's topic, the issue of how atomic clock frequencies can depend on motion relative to the different observers. It may well be that engineers concerned with NAVSTAR do make allowances for relativistic time dilation, but I would also expect them to make overriding empirical adjustments which make the whole system function by extrapolation techniques. Otherwise, they must know what is happening to those wild 'ticks' and should come forth and answer the specific question posed by Dr Essen.

Finally, I draw attention to a comment by Professor Santilli in his book on 'Ethical Probe on Einstein's Followers in the U.S.A. – An Insider's View' (Alpha Publishing, 1984). He tells the story of how NASA found they could not predict where SKYLAB would fall on its return to Earth and how a high governmental officer urged more consultation with relativity experts. The NASA scientist replied "If a professor comes in here with his relativities, he will be chased out of NASA's premises".

H. Aspden,
Department of Electrical Engineering,
Southampton University

In his article in the January 1988 issue, Dr Essen misrepresents the treatment of the 'twins paradox' in the Special Theory of Relativity. The situation envisaged has two experimenters, initially moving together without acceleration; one remains unaccelerated; the other travels in a space ship which accelerates away for time in a straight line and then undergoes three further accelerations, in the same line, to return to its original relation to the stay-at-home. The supposedly paradoxical behaviour predicted by SR is that the stay-at-home should believe the journey to have taken a greater time than that measured by the traveller. For convenience there should be such a long period of unaccelerated movement on both legs of the journey that the time spent accelerating may be neglected. That we can imagine this makes it plain that the acceleration is not in itself the source of the unexpected behaviour. The experiment has not been done in this form but a simpler version without return to the starting point provided one of the first experimental verifications of SR, although its numerical accuracy was poor. A later version involving curved paths is rather harder to analyse but yields very precise confirmation of Einstein's predictions. The first successful experiments

FEEDBACK

involved high velocities but the curved path form of the experiment has been performed at low speed. In spite of the problems of measuring the very small effects predicted this also confirms the theory.

The basis of your correspondent's criticism of SR is a symmetry it is supposed to postulate between the two experimenters' experience which would make an asymmetry in recorded time impossible. First we can see that there is no particular symmetry between the physical experience of the two: if they are equipped with accelerometers these will record entirely different sequences of readings. SR is a physical theory of measurement so it must, if it is to be acceptable, take account of this. How does it do so?

With Einstein we begin by noting something that seems more obvious now than it did 83 years ago: that experimenters travelling without acceleration can record the time and position of their experiments using a rectangular coordinate system and synchronised clocks fixed at convenient places. The assumptions we make are (i) Einstein's principle of SR: that all such experimenters will discover the same laws of nature (Lenz's Law etc.) and (ii) that they will measure the same velocity of travel for light, in free space. From these assumptions it can be deduced that the coordinates and times which different experimenters measure for the same event should be related by linear equations. If suitable axes are used these take the form known as the Fitzerald-Lorentz transformation. While it is possible to believe that the assumptions do not square with physical reality, though one would have to discount an awful lot of experimenting to do so, they have to be accepted in a discussion of the theory's internal consistency, as do the mathematical conclusions. (Unless an algebraic error can be discovered.)

In describing our experiment it is natural to use coordinate and time systems in which the experimenters are at rest. Three are required: one for the stay-at-home and two for the traveller, one on the outward path and another for the return. To relate measurements in any pair of these it is, in SR, necessary to use a Fitzgerald-Lorentz transformation, even though the same physical measuring systems may be used at all times by the traveller. The analysis is quite easy using the fixed experimenter's coordinates: more complex from the traveller's point of view, because more coordinate systems must be used, but both versions yield the same result: the traveller's clock will record a shorter travel time than the stationary one.

Michael Weatherill
St Andrews
Scotland

I appreciate the prominence given to my short article and hope that it will make the relativitists think and help the doubters. Unfortunately several phrases have been omitted, disturbing the logical sequence of some points of the argument, and I should be grateful if a correction could be published in your next issue. The sentence beginning on line 32, p127 (omitting the lines in heavy type) should read "One of the predictions of the theory was that a moving clock goes more slowly than an identical stationary clock when viewed from the position of the stationary clock."

On line 15, from the bottom of the middle column of p127 after "stages of the journey" it should read "As before, he concluded that the time recorded by the moving clock was less than that recorded by the stationary clock." Finally in line 13 of the third column of p.127, insert after "nanoseconds" "and yet the result was claimed to be accurate to 10 nanoseconds."

L. Essen
Leatherhead
Surrey

Flow chart

The flowchart technique proposed by David Sweeney in the August 1987 issue does very little to solve the real problems associated with this old but far from reliable system of logic design.

The problems with a graphical flowchart technique are twofold:

- the lack of any method of imposing structure, which usually leads to obscure and tangled code – difficult to debug, understand and modify;
- the difficulty in updating, maintaining and printing graphical documentation.

In an ideal software world, and following established ground rules for structured design, these problems would be solved by a universally powerful, flexible and friendly language.

In the real world, where many designers are still working with assembler or C, a high – level design technique (such as flowcharting) is essential. The solution I have adopted to the problems above is to use a text-based system which solves the maintainability and printing problem, incorporating a pseudo-high-level language to aid in imposing structure. This idea is of course far from new.

The advantage of this approach is that you can choose all the best features of your favourite language(s) and add new constructs or functions unique to your application. The language I use is heavily based on Algol (which was/is extremely readable), leavened with bits of BASIC. (Complex data structures and I/O techniques are not relevant to my application.) For example here is the LINEGEN algorithm from Mr Sweeney's article

```
begin
    call INITIALISE LINEGEN
    repeat
        call PLOT (x,y)
        x = x + 1
        if b<0 then b = b + a
        else
        begin
            y = y + 1
            b = b + c
        end
    until x = XIST + 1
end
```

It should be noted that the action of the algorithm is not identical to the original in that b and possibly y are different on exit. This follows from the good established practice of structured design in which loops are only exited at the beginning (while loops) or at the end (repeat.. until loops). A flowchart is the graphical equivalent of a GOTO!

A danger of a graphical approach to a high-level design is that, once complete, the difficulties of updating and issuing the design may preclude it ever being done. The original design then gets lost in a cloud of later additions and bug fixes. The above technique is supportable on any word processing system with a standard printer.

C.I.Perkins

Getting to grips with electromagnetism

I have always thought that electromagnetism should not be a book subject, and I have waited for the technology to arrive which would make visual communication possible. Finally it came, and I have spent most of the last year developing moving computer graphics which would give the viewer a proper grasp of the subject. I now have more than half an hour of moving graphics which run on an Acorn Master. It also can be seen as a VHS videotape, but quality is much degraded. All the content is conventional.

I have held back on selling these products because of fear of piracy, and I shall be very grateful if any readers can advise me on how to deal with piracy of an Acorn Master disc and also of a VHS videotape.

Ivor Catt
St Albans
Hertfordshire

PT 68K-2 SINGLE BOARD COMPUTER KIT

Designed around the powerful MC68000 microprocessor the PT 68K-2 is an easy to build single board computer kit.

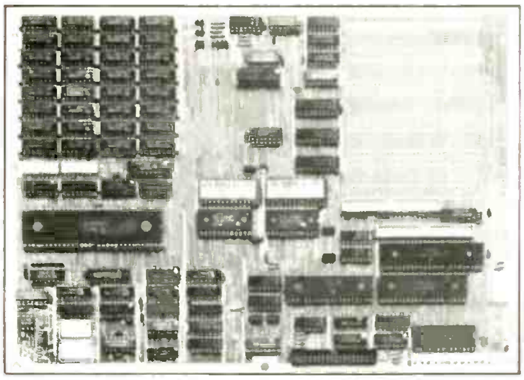
When fully configured the PT 68K-2 becomes a full feature system that supports over 1M byte of memory, floppy and hard disk drives, serial and parallel I/O and provides extensive expansion capability.

User expansion of the PT 68K-2 is suported by way of six on-board IBM PC/XT compatible I/O ports. This gives access to a wide range of low cost PC add-on boards such as colour adaptors and Western Digital Winchester controller cards.

Two powerful disk operating systems are supported:

SK★DOS – a low cost, single user DOS compatible with the popular FLEX disk operating system. SK★DOS even runs existing FLEX software.

OS-9/68K – the first choice for serious 68000 users. A Unix like real-time multi-tasking/multi-user DOS with a wide choice of languages.



PT 68K-2 specification:

Processor	– MC68000 8MHz clock, optional 10, 12.5, 16MHz clock.
Memory	– 1024K DRAM, no wait states. 128K EPROM. 4K SRAM.
Floppy disks	– Four floppy disk drives. (WD1772 FDC) 40/80 track, single/double sided/density.
Hard disks	– Winchester interface for WD1002A-HDO controller. PC/XT slots supports WD1002A-WX2 controller.
Serial I/O	– Four RS232 serial ports. (MC68681 DUARTS).
Parallel I/O	– Two 8 bit parallel ports. (MC68230 PIA) Interlocked handshaking. Two programmable interrupt timers.
RTC	– Battery backed real-time clock.
Expansion	– Six IBM PC/XT compatible I/O ports.
Power	– Requires 5V @ 2A and +/– 12V @ 20mA.
Size	– 12 × 8.5 inches.

The PT 68K-2 is supplied in kit form with all parts necessary to build a basic functioning 68000 computer. The user may then add additional parts to implement only those features required.

A debug monitor in eprom is included in the basic kit which supports I/O from either a serial RS232 terminal or PC/XT video card and IBM style keyboard.

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TELECOMMS TOPICS

BT stake in Japan

British Telecom is to become a partner in Japan's newest licensed international telecommunications operator, International Telecom Japan (ITJ). Its investment in ITJ means closer ties between British Telecom and some of Japan's most prestigious companies.

The founder shareholders of ITJ include Mitsubishi, Mitsui, Sumitomo, Matsushita, Marubeni, Nissho Iwai and The Bank of Tokyo. BT has a 2% share in the equity in ITJ. This represents an investment of 96 million yen ($750 000).

Siemens trunk transmission

Siemens has won a tender to supply British Telecom with digital radio relay systems. The first stage of the project covered by the contract is valued at about $1.8M for the supply, installation and commissioning of radio relay systems providing a transmission capacity of 140Mbit/s in the 6.7GHz band. With the changeover from analogue to digital technology, these systems will enable BT to provide high channel capacity combined with optimum transmission quality on the main routes between switching centres.

...and APT's local transmission

AT&T and Philips Telecommunications UK (APT) has recently received an order to supply digital transmission systems to British Telecom. The order covers the supply of 500 two-wire local line systems, to be used within BT's KiloStream digital private network operating at 2.4–64kbit/s.

These local-line units use a single two-wire line to provide high performance digital data links. Business users can be connected to the KiloStream service without the need to install special lines and they can use their existing data terminal equipment.

British Gas North Eastern is to improve its telephone communications facilities by installing an advanced digital private telephone exchange in its Tingley office, near Leeds. The new exchange, a dual Compact MD110 supplied by Thorn Ericsson, is capable of handling voice and data communications simultaneously.

Worth over £70 000, the order takes to ten the number of MD110 systems purchased by British Gas North Eastern with a total sales value topping £500 000. MD110 is a fully digital system and is designed to provide a wide range of facilities to meet present and future needs for voice and data communications. User features include automatic call-back, call transfer and follow-me facilities, abbreviated dialling and conferencing.

The transmission system comprises two units installed at the user's premises, with a matching unit within the local exchange multiplexer equipment, from where data traffic is routed into the KiloStream network. The echo-cancelling technology employed achieves duplex transmission over British Telecom's local network of pair type cable.

These systems are the first products wholly manufactured by APT in Malmesbury to be supplied to BT.

Timeplex/BA agreement

British Airways has signed a world-wide purchase agreement with Timeplex to provide time division multiplexers for the airline's future high-speed networking requirements. This follows an order from the airline for Timeplex equipment worth $700 000 (£400 000).

BA's relationship with Timeplex will be further enhanced by the decision to operate just one contact point within each company for all network installation and maintenance arrangements. As BA is UK-based, the Langley (Berkshire) headquarters of Timeplex and the BA Hounslow office have been authorized to represent their respective companies.

British Airways currently operates a world-wide statistical multiplexer network but is planning to develop its time division multiplexer network which will connect into other airlines and be used for seat reservation systems and other applications.

Plessey payphones

Plessey has won orders for payphones worth £5.5M in Australia and Singapore, markets dominated by the Japanese.

The order from Singapore, one of the most important markets in the Far East, calls for 4000 pre-pay card payphones initially and 500 000 payphone cards. The projected requirement is 16 000 payphones over the next five years.

"We believe the Singapore requirement represents the largest single tender ever issued for prepay card payphones", said Peter Brown, managing director of the Plessey payphone company.

The award also calls for credit card payphones and a cashless calling system which will be installed at Changi international airport and at major hotels in the republic.

The Plessey payphone company won its first order in Singapore for coin payphones in November 1985, providing a public international dialling capability from Singapore for the first time.

The award from Telecom Australia is to supply the next generation of payphones for the Australian rental market. The contract, which is for a supply period of three years at an estimated value of £2M per year, calls initially for 2000 Plessey Diamond payphones, to commence delivery in May 1988. This, the latest addition to the company's product range, is designed for use in hotels, bars, restaurants and other supervised locations. It accepts up to four different coins or tokens, gives cash box status information and has optional self-reporting facilities.

Post Office goes digital

The Post Office has chosen Plessey's ISDX switch as the backbone of its new digital telecommunications network. It will provide the first step towards modernizing the corporation's telecommunications services, with the aim of integrating voice and data transmission. It has placed an order for 17 large ISDXs (integrated services digital exchanges) to be installed in key centres around the country.

Dual processor ISDXs will be going into Post Office main transmit switching centres at Birmingham, Leeds, London, Manchester, Cardiff, Colchester and Edinburgh. The other ten switches will act as sub-tandems at Brighton, Leicester, Milton Keynes, Liverpool, Newcastle, Reading, Sheffield, Southampton and Preston.

One of the advantages of the Plessey ISDX is its DPNSS (digital private network signalling system) capability which allows all the offices to be connected to one private network.

Using a private network currently saves the Post Office at least £500 000 a year on call charges. It expects to make additional savings in future years by further integration of voice services.

Mediterranean fibre cable

Telefonica, the Spanish communications organization, has placed a contract valued at over £10M with STC for an underwater optical fibre telecommunications system to be installed in the Mediterranean.

To be known as Penbal-3, the contract calls for a 290km three fibre pair to link Barcelona and the Spanish island of Majorca. It is due for completion in June 1989.

The link will operate at 280Mbit/s on 1300 nanometres, giving a capacity of 3840 circuits per fibre pair, a total of 11 520 circuits before the use of circuit multiplication equipment. All cable for the system will be protected either by extra sheathing or by one or more layers of armour wires. The system design is similar to that which STC is supplying this year for TAT-8, the first transatlantic optical submarine cable.

Telecom Gold for health

The Department of Health and Social Security has negotiated a three-year contract worth £1.8M with Telecom Gold, BT's electronic mail service which is part of the Dialcom network, to improve the flow of information to the National Health Service.

Telecom Gold has already allocated nearly 500 mailboxes for use within the DHSS and NHS, and this figure could rise to around 5000 during the next three years. However, since the NHS is Europe's largest employer, its use of electronic mail could grow significantly faster.

Each month the DHSS faces a mammoth task in circulating some 40 000 pieces of information to each of 14 regional health authorities. It has been evaluating electronic mail as an alternative to other communication systems during the past year.

This information, previously telephoned or posted, ranges from crucial and time-sensitive items such as alerts on banned drugs and hazard warnings to general operational circulars and consultation on the content of Parliamentary business.

Plessey locks up lans

Plessey Crypto has launched Lanlok MLS-100, a multi-level security system for local area networks. It is claimed to be the first system in the world that has been designed to meet B2 classification for multi-level secure systems, as defined by the US National Computer Security Centre 'orange' book, together with a choice of encryption algorithms to enable widespread application in finance, commerce and industry.

According to the company, its introduction will enable industry and commerce to reduce its investment in costly computer equipment. This is because Lanlok does not permit any access to data by unauthorized personnel. It is therefore unnecessary to install multiple computer systems for use with information of different levels of confidentiality since the system design criteria required to meet B2 classification ensure that the secure local area network could not be fraudulently used. B2 is one of the highest attainable levels of security classification and as such Lanlok gives the commercial user a degree of security only normally used by the Government.

A typical Lanlok installation would comprise a single network security centre and multiple network security devices and secure lan interface units, defined by the size of the network. All data that passes around the secure lan is encrypted using either the Data Encryption Standard or a Plessey Crypto proprietary encryption algorithm.

Lloyds invests in IT

As part of Lloyds Bank's £570M information technology project designed to streamline office systems in the bank's branches so as to raise service to customers, it is to install approximately 28 000 terminals and controllers.

Data cabling will be provided by BT to connect the terminals in each of 1200 branches to their controllers. In turn these will link the terminals to the bank's new nationwide integrated voice and data network being set up under the project, giving access to more than 6000 computer devices. The cabling is planned to act as a token ring local area network capable of operating at rates up to 16Mbit/s.

UK first with pan-European demonstrator

What is believed to be the first demonstration of a prototype for the pan-European digital cellular system has been carried out in London – probably the most demanding area in topological terms, with the exception of some parts of the Swiss alps.

A two-year experimental programme has been undertaken by GEC-Marconi, British Telecom Research Laboratories and Racal Research with part funding by the Department of Trade and Industry. The experimental system constructed in this project consists of three identical pieces of equipment, forming the two ends of the radio-telephone system, plus a 'spare' unit.

One set was mounted at a fixed location (a British Telecom building in London called Riverside House). A second set was mounted in a vehicle so that the communications link could be tested under realistic mobile conditions: this was driven around a chosen route, and system performance was monitored. In some experiments, the third set was used as a source of interference. The measurements were partly objective (digital error-rate), and partly subjective voice communication tests, using conversation between people at the two ends. This system can be considered a "validation tool" – validation of the specification is scheduled by next year. The technical standards, developed by the Special Mobile Group of the Conference of European Posts and Telecommunications (CEPT), are already 80-90% complete. They should be finished in the next few months and so give adequate time to meet the fully-defined specification.

After the demonstration the Industry Minister, John Butcher, said: "This new system is proof that industrial collaborative research and development works. As a result of leading companies working together, Britain can now justifiably claim to be ahead of the pack and making the fastest progress in this new technology. By being the first in Europe to demonstrate a working system that meets the new European standards we are poised for growth in a major market of the future."

He made the point that, from being behind three years ago, Britain is today up alongside other European countries and will be able to compete effectively with other countries in this market.

Rural telecomms conference

An International Conference on Rural Communications to be held at the Institution of Electrical Engineers in London UK, 23–25 May, 1988, will report on recent advances in the provision of modern telecommunication services to the world's rural communities.

The conference will feature sessions on policy, switching, radio, optical fibre, satellite and planning. Sir Donald Maitland, chairman of the Independent Commission for Worldwide Telecommunication Development 1983-85, will give the keynote address.

Further information from Conference Services, IEE, Savoy Place, London WC2R 0BL; tel. 01-240 1871, ext. 222.

Telecomms Topics is compiled by Adrian Morant.

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Microcoding and bit-slice techniques

Part 3 – designing an instruction set for the demonstration processor, and producing the microcode required to implement it.

A. N. EDMONDS

In the first of my previous two articles* I discussed some of the techniques used in bit-slice design and described an illustrative 16bit processor. My second article looked at some topics in the use of software tools for producing microcode. This final article combines the subjects covered and completes the demonstration processor by describing an instruction set for it, and the microcode required to implement the instruction set.

Full source listings for the microcode are much too long to include here, but I will show the coding of a few important instructions and you should be able to infer the rest.

The demonstration processor and its instruction set are, as implied, purely conceived to render understanding of their structure easy, and to introduce the concepts they embody. Nonetheless I have tried to make them practical and useful.

INSTRUCTION SET

Designing microcode for the demonstration processor is made easier by choosing a simple instruction set, and this also has the benefit of being in vogue. Although my processor does not possess all the attributes of a reduced-instruction-set computer (risc), it includes some of the more important ones.

Whenever the frequency of use of instructions for a particular processor have been measured it has been found, as you would expect, that simple instructions like those for loading and unloading of registers and simple arithmetic occur far more frequently than the more complex instructions. This is also true of addressing modes: the more complex modes are used very infrequently.

It is clearly the trend to write software in a high-level language. With high-level languages, the usage of processor instructions is determined by compiler writers, who tend to use a subset of the instructions available for a traditional processor, often excluding the more complex. The risc theory is that by eliminating the more complex instruction types and concentrating on the most frequently used ones, the design can be streamlined and the net speed of the processor increased.

There is nothing wrong *per se* with a processor having a large and complex instruction set. However, if that instruction set over-complicates the instruction decoding and requires complex hardware in the data path, then the cycle time suffers and the processor becomes slower. Most of the discussions on the virtues of risc assume that a single-chip processor is being designed, and concern the relative merits of adding extra processes and a larger control section when silicon area is constrained.

In this design we have large amounts of space for storing microcode and no real constraints other than the effects of the microcode on cycle time. Table 1 shows the instruction set I have chosen. The load-and-store instructions operate between registers and memory. Every other arithmetic or logical instruction acts only on one or more registers.

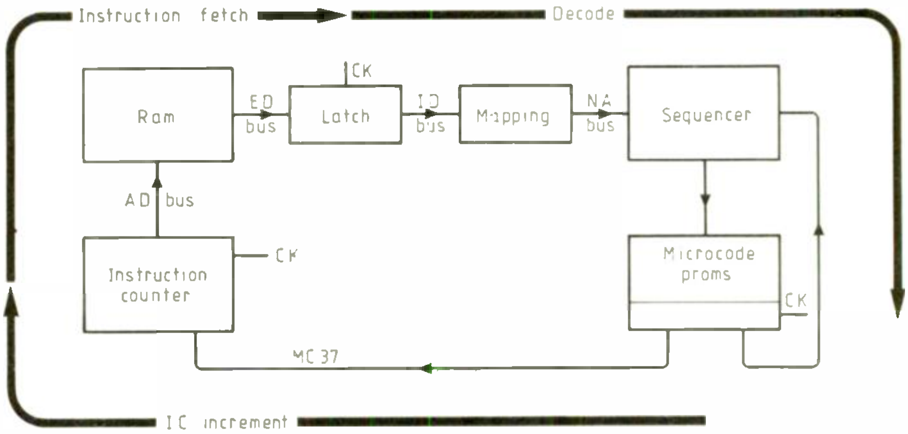

Fig 1. Parallel actions during an instruction fetch.

Table 1. Demonstration processor instruction set.

Name		Code																2nd word (if any)
LOAD	IMM	0	0	0	0	0	0	D	D	D	D	D	X	X	X	X	X	TTTTTTTTTTTT
LOAD	DIR	0	0	0	0	0	1	D	D	D	D	D	X	X	X	X	X	AAAAAAAAAAAA
LOAD	REG	0	0	0	0	1	0	D	D	D	D	D	S	S	S	S	S	
LOAD	IND	0	0	0	0	1	1	D	D	D	D	D	S	S	S	S	S	
POP		0	0	0	0	1	1	1	1	1	1	0	S	S	S	S	S	
STORE	DIR	0	0	0	1	0	1	X	X	X	X	X	S	S	S	S	S	AAAAAAAAAAAA
STORE	IND	0	0	0	1	1	1	D	D	D	D	D	S	S	S	S	S	
PUSH		0	0	0	1	1	1	1	1	1	1	0	S	S	S	S	S	
AND		0	0	1	0	X	X	&	&	&	&	&	S	S	S	S	S	
ADDC		1	1	1	0	X	X	&	&	&	&	&	S	S	S	S	S	
SUB		1	0	0	0	X	X	&	&	&	&	&	S	S	S	S	S	
SUBC		1	1	1	1	X	X	&	&	&	&	&	S	S	S	S	S	
OR		0	0	1	1	X	X	&	&	&	&	&	S	S	S	S	S	
EXOR		0	1	0	0	X	X	&	&	&	&	&	S	S	S	S	S	
ADD		0	1	0	1	X	X	&	&	&	&	&	S	S	S	S	S	
IF	DIR	1	0	0	1	0	1	C	C	C	C	X	X	X	X	X	X	AAAAAAAAAAAA
IF	IND	1	0	0	1	1	1	C	C	C	C	X	S	S	S	S	S	
SHIFT	LO	1	0	1	0	0	0	&	&	&	&	&	X	X	X	X	X	
SHIFT	LI	1	0	1	0	0	1	&	&	&	&	&	X	X	X	X	X	
SHIFT	RSE	1	0	1	0	1	0	&	&	&	&	&	X	X	X	X	X	
SHIFT	RO	1	0	1	0	1	1	&	&	&	&	&	X	X	X	X	X	
GOSUB	DIR	1	0	1	1	0	1	X	X	X	X	X	X	X	X	X	X	AAAAAAAAAAAA
GOSUB	IND	1	0	1	1	1	1	X	X	X	X	X	S	S	S	S	S	
RETURN		1	1	0	0	0	X	X	X	X	X	X	X	X	X	X	X	
NOP		1	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	

D destination, S source, & source and destination, X don't care, C condition, T data value, A address.

Values for C are:

0000	(Sign Ex-or overflow) Or zero
0001	Sign Ex-or Overflow
0010	Zero
0011	Overflow
0101	Carry
0110	Zero and not carry
0111	Sign
1001	True/*force jump*/

All other values are illegal.

The addressing modes are very simple:

- IMM represents immediate addressing; the next word forms the data.
- DIR represents direct addressing; the next word is the address for the data.
- REG represents register addressing; data is contained in a register.
- IND represents indirect addressing; a register contains the address for the data.

More complex addressing modes can be produced with several instructions. For instance, if register R5 were used as a data pointer, register-relative addressing could be performed with the following, using R6 as a scratchpad:

LOAD IMM offset R6
ADD R6 R5
LOAD IND R6.

This would require only six processor cycles.

PIPELINING

Bit slice systems have a natural facility for parallel action. It is possible for instance to fetch a new instruction while another instruction is decoded and a third is being performed. These three functions are sequential when considering a single instruction, but throughput can be considerably increased by overlapping them. Thus, while instruction 1 is being completed, instruction 2 can be decoded, and instruction 3 can be accessed, Table 2.

Table 2. Pipelining for instruction fetching and decoding assuming instructions requiring two, one and three cycles.

Cycles	1	2	3	4	5	6	7	8
Data bus	I1	I2		I3	I4			I5
Data latch		I1	I2	I2	I3	I4	I4	I4
Mapping prom		A1	A2	A2	A3	A4	A4	A4
Sequencer		J	C	J	J	C	C	J

In the nth instruction code, An is the microcode start address for instruction In, J causes the sequencer to jump to address An in the next cycle, and C (continue) causes the sequencer to step to the next sequential microcode address.

Since the pipeline is controlled by microcode, you must ensure that each instruction written maintains the pipelining. It is easiest to do this if you produce rules and adhere to them. The two rules for this processor are:

- The last cycle of each instruction must fetch a new instruction and decode the previous one.
- Every instruction must fetch as many instructions as it uses.

Rigorous application of these rules will ensure a trouble free hand-over of control from one instruction to the next. Figure 1 shows the events that occur in the last cycle of each instruction.

CYCLE REQUIREMENTS

The 29117 in the demonstration circuit (January issue) is a 16bit bipolar microprocessor. It uses one of 32 sixteen-bit registers and an accumulator or data input as operand sources. Any two of these can be used; this means that when a two-operand instruction such as add or subtract is performed, one of the operands must be moved into the accumulator from the register file before proceeding. Thus the minimum number of cycles for a dyadic instruction is two; the monadic instruction SHIFT will run in one cycle.

DEFINITIONS FILE

Table 3 shows the names assigned to each field in the microcode word. Space does not permit the inclusion of the entire definitions file, but List 1 shows excerpts from it in Metastep syntax. Macros have been constructed to enable the 29117 to be programmed in AMD mnemonics. Detailed descriptions of the arithmetic and logic unit are given in the AMD 29117 data sheet.

The other functions require only a further four macros. They are:

JUMP (address)
BRANCH (address)
FETCH_IC
FILL_PL.

All macro names are denoted by upper-case letters. Jump forces the next microcode word executed to be the one at the given address. Branch does the same if the condition line to the 2910 is low; if not the next microcode word is used. Macro FETCH_IC outputs the value of the instruction counter onto the address bus, increments the IC value and latches the resulting word from the ram. It then makes the sequencer jump to the microcode address pointed to by the mapping prom. Macro FILL_PL does the same as FETCH_IC but does not force a microcode jump.

Table 3. Microcode-word bit allocations.

Bit	Allocation
00-11	Next address field
12-15	2910 instruction
16-20	Register address
21-31	29117 instruction
32	Read/write
33	Enable IC to ID bus
34	Enable IC to address bus
35	Enable a.l.u. to address bus
36	Force sequencer condition
37	Increment instruction counter
38	Load instruction counter
39	Enable a.l.u. to data-bus latch
40-42	Register control
43	Register value
44	Enable a.l.u. to address clock
45	Status load
46	Data-latch enable
47	Latch instruction

ASSEMBLY FILE

The instructions in Table 1 can be encoded into just 69 microcode words. Of these, the shortest instructions are only one cycle long; the longest is eight cycles for GOSUB DIR.

List 2 shows several examples in Metastep syntax, the first of which is the ADD instruction. With reference also to the circuit diagram in the first article, the first line of the ADD instruction defines the 29117 register address as the value in bits 0-4 of the instruction. Contents of this register are moved to the 29117 accumulator by the second line of the instruction. Note that register parameter R0 is a dummy parameter since the value is not provided by microcode. Also note that no sequencer instruction is given in this cycle. The default is set in the definitions file to be CONT, which moves the sequencer on to the next sequential microcode word.

At the start of the second cycle, updating of status information is enabled. Next, bits 5-9 of the instruction word are selected as the register address for the a.l.u. The next line adds the accumulator and the selected register, and places the result into the register. Once more the parameter R0 is a dummy parameter. Finally, FETCH_IC refills the pipeline and transfers control to the next instruction.

Example two in List 2 is the IF_DIR instruction. Bits 6-9 select one of eight testable conditions of the a.l.u. status by way of IC_{20}. The 29117 puts the active-high result of the test on the CT pin, which is connected to the ACTIVE LOW CC input of the 2910. The first instruction line thus moves microcode control to the label NO_CHANGE if the condition fails.

In the next two instruction lines, the latch formed by $IC_{10,11}$ is enabled and the results from the latch are transferred to the a.l.u. accumulator. A FILL_PL macro is performed to top up the pipeline. This only has an effect if the jump to NO_CHANGE is made. If not the data so obtained is overwritten. If the jump is not taken the instruction counter is loaded with the a.l.u. accumulator content. Instructions PTI and NO_CHANGE refill a now invalid pipeline.

Indirect storage is illustrated in the last instruction example, STORE_IND. In its first

List 1. Excerpts from the definitions file.

```
demopro:      instruction version ('1.00'), length(48);
nextaddr:     bits(11... 0), default(0);
force:        bits(36), values(b'0':TST, (b'1': PASS), default (TST);
id__con:      bits(46,33), values(b'01': ed__to__id, b'10': ic__to__id, b'11': none), default(none);
r/w           bits(32), values(b'0': write,b'1': read), default(read);
ad__con:      bits(35,34), values(b'10' : ic, b'01' : alu__out, b'11' : none), default(none);
inc__ic:      bits(37), values(b'1': inc, b'0': no__change), default (no__change);
load__ic:     bits(38), values(b'1': 1d, b'0' : no__change), default(no__change);
ck__alu__ed:  bits(39), values(b'1': no-clock, b'0': clock),default(no__clock);
reg__con:     bits(42...40), values  (b'111' :  noreg,
                                      b'110' :  destination,
                                      b'101' :  source,
                                      b'011' :  control)
                                                default(control);
reg__load:    bits(43), values(b'0': 1d, b'1': noload), default(noload);
alu__add__ck: bits(44), values(b'0': 1d, b'1': noload), default(noload);
status__load: bits(45), values(b'0': 1d, b'1': noload), default(noload);
latch__inst   bits(47), values(b'0': 1d, b'1' :noload), default(noload);
endinstruction;
```

line, bits 5-9 of the instruction word are selected as the register giving the store address, its second line outputs this value, and its third line latches the value into $IC_{18,19}$.

At the start of the next cycle, the data register is selected through bits 0-4 of the instruction word. This data is moved to, and latched into $IC_{16,17}$. In the penultimate cycle, address and data are output to the ram through their respective buses. A FETCH_IC macro terminates the sequence.

MAPPING PROM

Table 1 and a list of the start addresses of each instruction give all the data required to produce the mapping prom. You can see for instance that addresses 0 to IF_{16} should contain the microcode address of the load-immediate function. Similarly addresses 450_{16} to $46F_{16}$ should contain the address of IF_DIR. All spare locations represent an illegal instruction and should be filled with zeros, forcing a reset. I have positioned the reset routine at microcode address 0.

Having decided the above, one still has the problem of producing a hexadecimal file with which to program the mapping prom. One good solution is a product called PLEASM from MMI: it consists of software that enables you to program a prom as a programmable logic element using Boolean algebra and is thus perfect for this application.

I hope that the above and my previous two articles make the subject of microcoded systems more accessible to you. I do not intend that my demonstration processor be taken too seriously. It was designed to be easily understood and is incomplete in several major respects. The hardware is, however, capable of 3 Mips and illustrates that the expertise and design time required to develop a fast dedicated processor are not as daunting as you might have believed.

Demonstration-processor software can be obtained by sending a PC-compatible 5¼in disc formatted for double-density in a self-addressed disc mailer with return postage to Microcode, *E&WW* Editorial, Room L302, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

List 2. Assembly code for some key instructions.

```
ADDI:          reg__con = source,             /* address source */
               SOR W MOVE SORA RO,            /* move source to acc */
               FILL__PL;                      /* fill pipeline */

               status__load = 1d,             /* modify status */
               reg__con = destination,        /* address destination */
               TOR1 W ADD TORAR RO,           /* perform function */
               FETCH__IC;                     /* finish */

IF__DIR:       BRANCH NO__CHANGE,             /* tests CC*/
               id__con = ed__to__id,          /*enable latch output/
               SONR W MOVE SOD NRA,           /* transfer data to Acc*/
               FILL__PL;                      /* in vain if branch */

               SONR W MOVE SOA NRY,           /* output new IC value/
               load__ic = 1d;                 /* update ic */

PTI:           FILL__PL;                      /* fill pipeline */

NO__CHANGE:    FETCH__IC;                     /* and again */

STORE__IND:    reg__con = destination,        /* dest. gives address*/
               SOR W MOVE SORY RO,            /* transfer ram to YO */
               alu__add__ck = 1d;             /* latch YO */

               reg__con = source,             /* select register */
               SOR W MOVE SORY RO,            /* move data to YO */
               ck__alu__ed = clock;           /* latch YO to ED */
               ad__con = alu__out,            /* enable address */
               r/w = write;                   /* write data */
               FETCH__IC;
```

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

**The previous two articles appeared in the January and March issues of E&WW.*

Artificial intelligence in silicon

From the unlikely source of an audio company comes a combination of chips that can follow object-oriented instructions. The company is Linn Products which regularly tops the lists in hi-fi magazines for quality audio equipment. Automating its warehouse required complex computer instructions and a software system was devised to provide all the stock control and management of the inventory. The software proved to be so complex that it worked very slowly on conventional computers. Linn, with the aid of Professor David Harland, then went on to develop hardware to run it. The result is the Rekursiv chip set and the foundation of Linn Smart Computing in Glasgow to market this new technology.

'Objects' in the computer sense are blocks of data or information that are tagged with a series of labels. Labels identify the objects and include information on their size and type. They are shifted about within memory by 'paging' the label. Parts of the tags attached to an object can be mathematical operations so that, for example, if a multiply tag is attached to an numerical object, whenever it is called, the processor 'knows' automatically that it should be multiplied with no further programming. Other labels can slot an object into a hierarchy of objects which can have several levels in a 'tree' structure. It is then possible to perform operations on the whole tree or specific parts of it without calling each individual branch.

The processor uses very high-level instructions, each of which performs a great deal of processing for any given operational code. This results in very few instructions needed for a complex operation. Instructions are flexible and can be microcoded for specific applications and then held in rom. Instructions can refer to themselves in a recursive manneri hence the name.

A major difference is the organization of memory, which is not addressed in the conventional sense; objects are referred to by their labels and not their position in memory.

Discs and internal object-store memory are considered as part of the same domain. As objects carry their labels about with them, they are dealt with in the same way whether in the core or out on disc. A dedicated processor, the Novix Forth chip, is used to transfer objects to and from disc. Tables of the objects and their types and sizes are stored in a special section of memory, separate from the main store of objects which are controlled by an object-oriented memory management chip. This also means that the controlling language is the operating system and that all file management is dealt with automatically without the interposition of another process.

Other principal components are the central processor, which has the same functions as the 32-bit AMD 29203 processor with the addition of an integrated barrel shifter and multiplier, and the microprogrammable sequencer and stack control chip. These three chips make up the Rekursiv set and are made for Linn by LSI Logic in 1.5μm c-mos. A complete processor board includes 2Mbyte of s.ram allocated to specific tasks and a large amount of d.ram which, with the disc, forms the object store.

All is available on a board which is VMEbus compatible, so the board can be fitted into a VME workstation such as Sun or Apollo. Professor Harland at Linn, leader of the team that designed the system, stresses that these are used as vehicles and that there is great potential for manufacturers to design systems and other artificial intelligence programmes, in computer-aided design, and in database management systems, operating at high speed.

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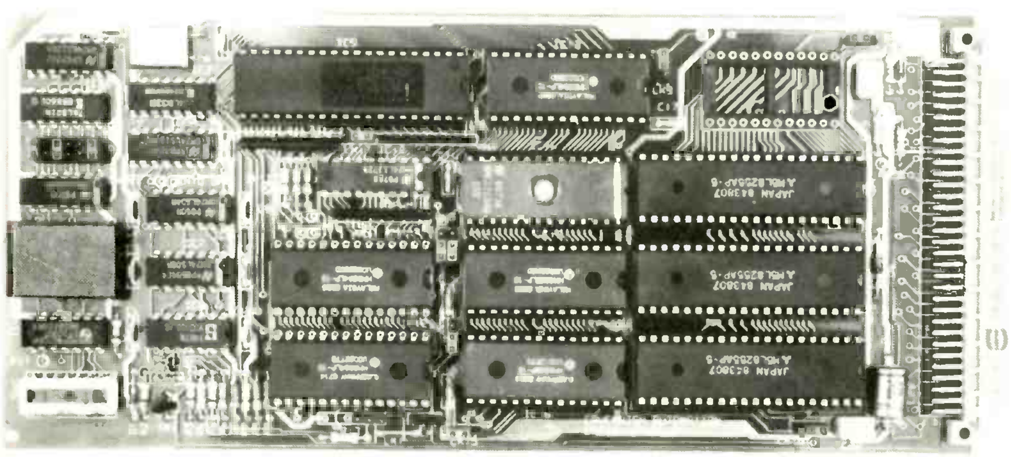

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Inductive peaking circuits

Data on the design of peaking circuits for high-frequency amplifiers must normally be gathered from a large number of sources and is often incomplete. This article presents all the relevant information on the eight circuits in tabular and graphical form.

PETER STARIČ

Inductive peaking is still one of the most widely used methods of extending the bandwidth or decreasing the risetime of a wide-band or pulse amplifier. Unfortunately, a design from scratch entails lengthy and complicated calculations, particularly when one looks for an optimum step response, and design information must be gathered from a considerable number of sources. In order to avoid these handicaps, the author has composed a table with all data important in the design and with two diagrams (Fig.2 and Fig.3) to indicate relative performance of the peaking circuits.

In general, two types of inductive peaking are mostly used: the maximally flat amplitude circuit (m.f.a.) and the maximally flat envelope-delay type (m.f.e.d.). M.f.a. circuits have a so-called Butterworth pole placement, while m.f.e.d. networks have a Bessel-pole placement (sometimes called Thomson-pole placement). M.f.a. circuits are suitable for steady-state sinusoidal signals: their transmission of step signals results in an excessive overshoot. For the amplification of step signals, m.f.e.d. circuits should be used. They have a relatively small overshoot, but the beginning of their high-frequency roll-off is not as steep as with their m.f.a. counterpart and they also have a slightly smaller bandwidth/risetime improvement. To give the designer the freedom of selection, the table shows data for both types of network. Networks with Chebyshev and Cauer pole placements are not treated here because of the ripple in the passband, which is characteristic of these types of circuits.

In addition to the design data, such as circuit elements and bandwidth or risetime improvement, the table also gives data for poles and zeros (whenever zeros appear) to allow the calculation of the frequency-, phase- and time-delay responses. To make more accurate plots of the responses, one can use the formulae for m.f.a. frequency-response and m.f.e.d. step-responses given in the table. For the less-often needed phase response and time-delay response, the reader should use the general equations given in the text.

I intentionally deleted the five-pole and two-zero series-shunt peaking (Dietzold) network[3], which is a combination of type (b) and type (e) circuit. The reason is that a better performance with less effort can be achieved with a T-coil, three-pole circuit (h)

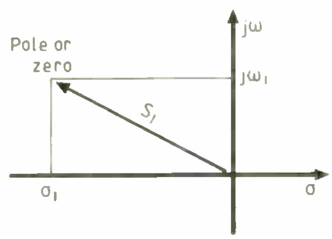


Fig.1. The real σ_i and imaginary component ω_i of the pole S_i.

Fig.2. Plots of the frequency responses are given in the formulae in the Table. Some circuits have zeros which are not mentioned in the figure and are only given in the table.

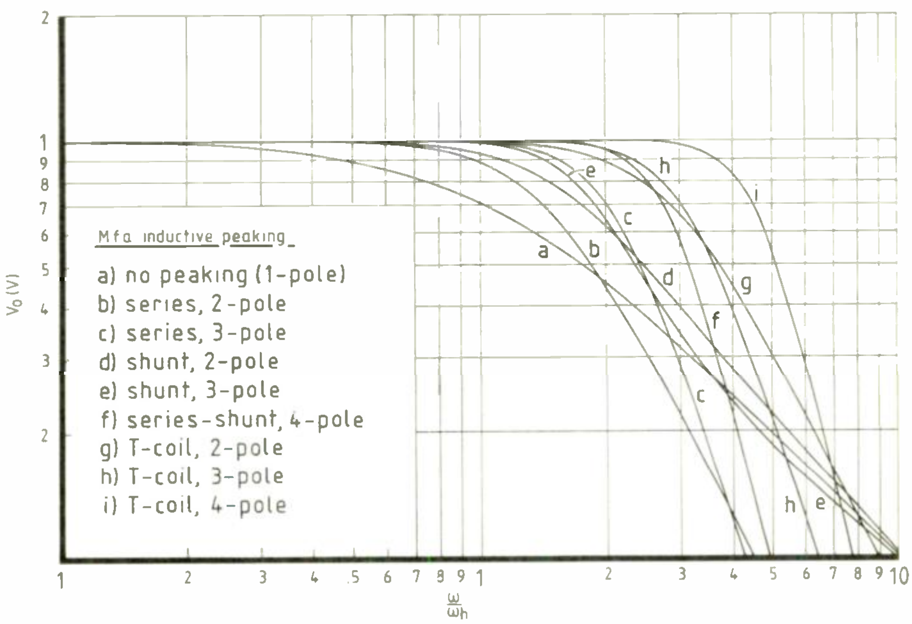
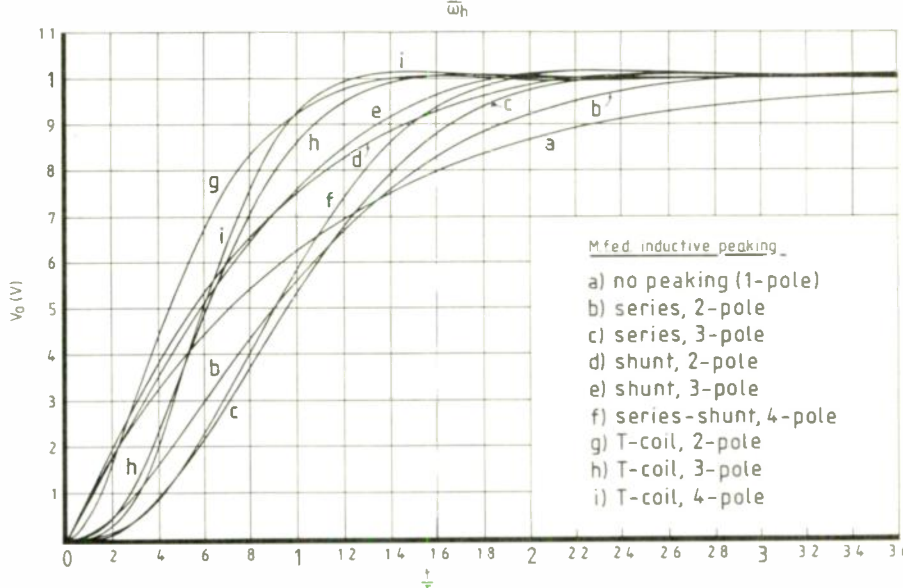
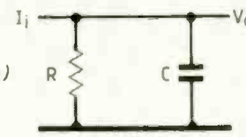


Fig.3. Plots of step responses as given in the formulae in the table. Some circuits have zeros which are not mentioned in the figure and are only given in the table.



(a)



poles
$\sigma_{1p}=\omega_o=1/RC$
$\eta_b=1$

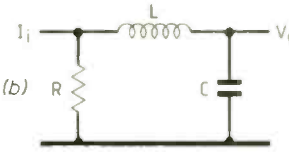
$T=RC$
$\eta=1$
$\tau_o=2.2RC$

response

$$F(\omega)=\frac{1}{\sqrt{1+(\omega/\omega_o)^2}}$$

$$f(t)=1-e^{-t/T}$$

(b)



m.f.a
$L=0.5R^2C$
$\eta_b=\sqrt{2}$
$\omega_o=1/RC$

poles
$\sigma_{1p}=\omega_o$
$\omega_{1p}=\omega_o$

response

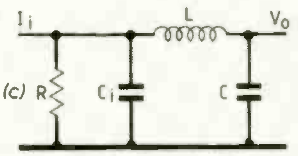
$$F(\omega)=\frac{1}{\sqrt{1+0.25(\omega/\omega_o)^4}}$$

m.f.e.d.
$L=0.33R^2C$
$\eta_r=1.36$
$\delta=0.43\%$

poles
$\sigma_{1p}=1.5/T$
$\omega_{1p}=0.866/T$
$T=RC$

$$f(t)=1-2e^{-1.5t/T}\sin(0.866t/T-0.524)$$

(c)



m.f.a
$L=0.67R^2C_{tot}$
$C_i=0.25C_{tot}$
$\eta_b=2$
$\omega_o=1/RC_{tot}$

poles
$\sigma_{1p}=\omega_o$
$\omega_{1p}=\sqrt{3}\,\omega_o$
$\sigma_{2p}=2\omega_o$

response

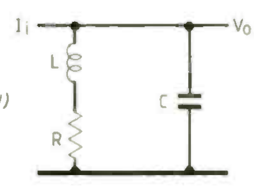
$$F(\omega)=\frac{1}{\sqrt{1+0.0156(\omega/\omega_o)^6}}$$

m.f.e.d.
$L=0.48R^2C_{tot}$
$C_i=0.17C_{tot}$
$\eta_r=1.82$
$\delta=0.75\%$
$T=RC_{tot}$

poles
$\sigma_{1p}=1.839/T$
$\omega_{1p}=1.754/T$
$\sigma_{2p}=2.322/T$

$$f(t)=1-1.951e^{-2.322t/T}-1.849e^{-1.839t/T}\sin(1.754t/T-0.540)$$

(d)



m.f.a
$L=0.414R^2C$
$\eta_b=1.72$
$\omega_o=1/RC$

poles
$\sigma_{1p}=1.208\omega_o$
$\omega_{1p}=0.978\omega_o$
zero
$\sigma_{1z}=2.416\omega_o$

response

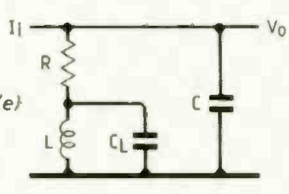
$$F(\omega)=\sqrt{\frac{1+0.172(\omega/\omega_o)^2}{1-0.172(\omega/\omega_o)^2+(\omega/\omega_o)^4}}$$

m.f.e.d.
$L=0.32R^2C$
$\eta_r=1.60$
$\delta=0.8\%$
$T=RC$

poles
$\sigma_{1p}=1.553/T$
$\omega_{1p}=0.833/T$
zero
$\sigma_{1z}=3.106/T$

$$f(t)=1-1.2e^{-1.553t/T}\sin(0.833t/T+0.985)$$

(e)



m.f.a.
$L=0.414R^2C$
$C_L=0.35C$
$\eta_b=1.84$
$\omega_o=1/RC$

poles
$\sigma_{1p}=0.850\omega_o$
$\omega_{1p}=1.577\omega_o$
$\sigma_{2p}=2.125\omega_o$
zeros
$\sigma_{1z}=1.412\omega_o$
$\omega_{1z}=2.197\omega_o$

response

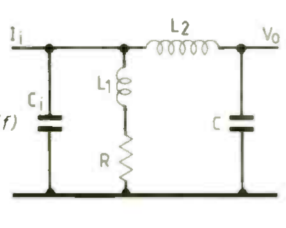
$$F(\omega)=\sqrt{\frac{[1-0.1449(\omega/\omega_o)^2]^2+0.1714(\omega/\omega_o)^2}{[1-0.1956(\omega/\omega_o)^2]^2+[1-0.1449(\omega/\omega_o)^2]^2(\omega/\omega_o)^2}}$$

m.f.e.d.
$L=0.35R^2C$
$C_L=0.22C$
$\eta_r=1.75$
$\delta=1.2\%$
$T=RC$

poles
$\sigma_{1p}=1.604/T$
$\omega_{1p}=1.791/T$
$\sigma_{2p}=2.248/T$
zeros
$\sigma_{1z}=2.273/T$
$\omega_{1z}=2.797/T$

$$f(t)=1-0.961e^{-2.248t/T}-0.683e^{-1.604t/T}\sin(1.791t/T+0.057)$$

(f)



m.f.a.
$L=0.143R^2C_{tot}$
$L_2=0.583R^2C_{tot}$
$C_i=0.40C_{tot}$
$\eta_b=2.75$
$\omega_o=RC_{tot}$

poles
$\sigma_{1p}=2.440\omega_o$
$\omega_{1p}=0.973\omega_o$
$\sigma_{2p}=1.075\omega_o$
$\omega_{2p}=2.471\omega_o$
zero
$\sigma_{1z}=6.803\omega_o$

response

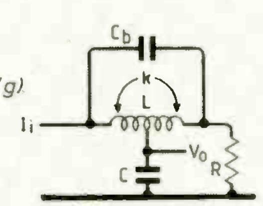
$$F(\omega)=\sqrt{\frac{0.02(\omega/\omega_o)+1}{[0.02(\omega/\omega_o)^4-0.49(\omega/\omega_o)^2+1]^2+[\omega/\omega_o-0.14(\omega/\omega_o)^3]^2}}$$

m.f.e.d.
$L_1=0.133R^2C_{tot}$
$L_2=0.467R^2C_{tot}$
$C_i=0.33C_{tot}$
$\eta_r=2.39$
$\delta=1.86\%$
$T=RC_{tot}$

poles
$\sigma_{1p}=2.125/T$
$\omega_{1p}=1.097/T$
$\sigma_{2p}=1.623/T$
$\omega_{2p}=3.162/T$
zero
$\sigma_{1z}=7.496/T$

$$f(t)=1-2.210e^{-2.125t/T}\sin(1.097t/T+0.799)-0.627e^{-1.623t/T}\sin(3.162t/T-1.195)$$

(g)



m.f.a.
$L=R^2C$
$k=0.33$
$C_b=0.125C$
$\eta_b=2.83$

poles
$\sigma_{1p}=2\omega_o$
$\omega_{1p}=2\omega_o$

$\omega_o=1/RC$

response

$$F(\omega)=\frac{1}{\sqrt{1+15\cdot62\cdot10^{-3}(\omega/\omega_o)^4}}$$

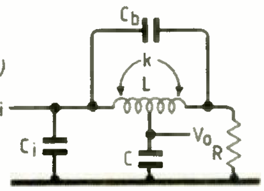
m.f.e.d.
$L=R^2C$
$k=0.5$
$C_b=0.083C$
$\eta_r=2.72$
$\delta=0.43\%$

poles
$\sigma_{1p}=3/T$
$\omega_{1p}=\sqrt{3}/T$

$T=RC$

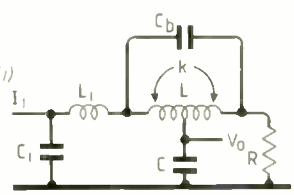
$$f(t)=1-2e^{-3t/T}\sin(\sqrt{3}\,t/T+0.524)$$

(h)



m.f.a.	poles	response
$L=R^2C$ $k=0$ $C_b=0.25C$ $C_i=0.33C_{tot}$ $\eta_b=3$ $\omega_o=1/RC_{tot}$	$\sigma_{1p}=1.5\omega_o$ $\omega_{1p}=2.6\omega_o$ $\sigma_{2p}=3\omega_o$	$F(\omega)=\frac{1}{\sqrt{1+1.367\cdot10^{-3}(\omega/\omega_o)^6}}$
m.f.e.d.	**poles**	
$L=R^2C$ $k=0.35$ $C_b=0.119C$ $C_i=0.28C_{tot}$ $\eta_r=2.78$ $T=1/RC_{tot}$	$\sigma_{1p}=2.886/T$ $\omega_{1p}=2.752/T$ $\sigma_{2p}=3.645/T$	$f(t)=1-1.951e^{-3.645t/T}$ $-1.849e^{-2.886t/T}\sin(2.752t/T-0.540)$

(i)



m.f.a.	poles	response
$L=R^2C$ $k=0.55$ $C_b=0.073C$ $L_i=1.71R^2C_i$ $C_i=0.17C_{tot}$ $\eta_b=4.46$ $\omega_0=1/RC_{tot}$	$\sigma_{1p}=4.121\omega_o$ $\omega_{1p}=1.707\omega_o$ $\sigma_{2p}=1.707\omega_o$ $\omega_{2p}=4.121\omega_o$	$F(\omega)=\frac{1}{\sqrt{1+6.387\cdot10^{-6}(\omega/\omega_o)^8}}$
m.f.e.d.	**poles**	
$L=R^2C$ $k=0.57$ $C_b=0.068C$ $L_i=0.65R^2C_i$ $C_i=0.22C_{tot}$ $\eta_r=3.45$ $\delta=0.83\%$ $T=RC_{tot}$	$\sigma_{1p}=4.732/T$ $\omega_{1p}=1.417/T$ $\sigma_{2p}=3.437/T$ $\omega_{2p}=4.341/T$	$f(t)=1-5.664e^{-4.732t/T}\sin(1.417t/T+0.486)$ $-1.648e^{-3.437t/T}\sin(4.341t/T-1.603)$

which makes Dietzold – and also a common series-shunt peaking circuit (f) which is given here merely for reference – obsolete.

EXPLANATION OF THE DATA

The inputs of the circuits shown are assumed to be fed from a constant-current source, for example a collector in the "upper" transistor of a cascode stage, and that the collector power supply, where the loading resistor is connected, has zero impedance to ground (a condition which is not easy to achieve). The more frequently used data in the table are:

- R = collector loading resistor [ohms]
- C = main stray capacitance [farads]
- C_i = input stray capacitance [farads]
- C_{tot} = C_i + C = the sum of all stray capacitances [farads]
- C_b = T-coil bridging capacitance [farads]
- L = inductance of the main peaking coil [henrys]
- L_i = inductance of the input peaking coil [henrys]
- K = coupling factor between both halves of the centre-tapped T-coil
- ω_u = $2\pi f_u$ = upper limit frequency without any peaking coils [radians]
- ω_h = $2\pi f_h$ = upper limit frequency with peaking [radans]
- η_b = bandwidth improvement factor = $\omega_h/\omega_u = f_h/f_u$
- δ = overshoot [%]
- τ_u = 2.2T = risetime without any peaking coils [seconds]
- τ_r = risetime with peaking coils [seconds]
- η_r = risetime decreasing factor = τ_u/τ_r
- T = RC_{tot} = time constant [seconds]
- σ_i = real part of the complex pole or zero [radians/second]
- ω_i = imaginary part of the complex pole or zero [radians/second]
- ω = frequency variable [radians/second = 2πHz]
- t = time variable [seconds]

In general, a pole or zero is composed of a real and imaginary part in the form, $s_i=-\sigma_i+j\omega_i$ as shown in Fig. 1. The imaginary part may occasionally be missing. If there is an imaginary part there are always two conjugate complex poles $s_{1p}=-\sigma_{1p}+j\omega_{1p}$ and $s_{2p}=-\sigma_{1p}-j\omega_{1p}$. Although all the poles and zeros lie on the left side of the complex plane, which makes all σ_i negative, this is not shown in the table, but is strictly observed in the formulae given: the pole figures should be entered in their absolute values.

The argument of the sine functions which appear in the step-responses is in radians.

In all cases, the input capacitance C_i is smaller than the output (or main) capacitance C. When the practice dictates an opposite capacitance ratio, the input and output port of the circuit can be exchanged without loss of performance (the reciprocity theorem).

USE OF THE TABLE AND DIAGRAMS

With the data for poles and zeros in the table, it is possible to calculate the frequency-, phase-, and envelope-delay response (time-delay response). Since the frequency responses are given for the m.f.a. networks only, the reader might want to calculate the frequency response of a m.f.e.d. network. To do so the values of zeros (σ_{iz} and ω_{iz}) and poles (σ_{ip} and ω_{ip}) should be entered in the (general) formula

$$F(\omega)=\frac{V_o}{I_i}=\sqrt{\prod_{i=1}^{n}\frac{\sigma_{iz}^2+(\omega-\omega_{iz})^2}{\sigma_{iz}^2+\omega_{iz}^2}}\cdot\sqrt{\prod_{i=1}^{n}\frac{\sigma_{ip}^2+\omega_{ip}^2}{\sigma_{ip}^2+(\omega-\omega_{ip})^2}}\quad(1)$$

to get the normalized frequency response. (The formulae in the table are not always in this form and are simplified where this can be easily done). When there are no zeros, the value 1 should be put instead of the first square root. (See Example 2).

To calculate the phase response, the following formula should be used.

$$\varphi(\omega)=\sum_{i=1}^{n}\tan^{-1}\frac{\omega-\omega_{iz}}{\sigma_{iz}}-\sum_{i=1}^{n}\tan^{-1}\frac{\omega-\omega_{ip}}{\sigma_{ip}}\quad(2)$$

If the circuit has no zeros, the first sum is zero. (See Example 1). A negative sign means a phase lag.

We can calculate the envelope-delay with the formula

$$\tau_e(\omega)=\sum_{i=1}^{n}\frac{\sigma_{iz}}{\sigma_{iz}^2+(\omega-\omega_{iz})^2}-\sum_{i=1}^{n}\frac{\sigma_{ip}}{\sigma_{ip}^2+(\omega-\omega_{ip})^2}\quad(3)$$

Again here, the first sum is zero if there are no zeros in the network. (See Example 1). A negative sign means a delay.

EXAMPLES

An m.f.a. amplifier has to be designed with a three-pole (and two-zero) peaking circuit, with the following data:

stray-capacitance C = 27 pF
desired bandwidth f_h = 15 MHz (upper limit frequency with peaking)

We select the circuit (e) and first calculate the non-peaked upper limit frequency on the basis of η_b.

$$\eta_b=\frac{\omega_h}{\omega_u};$$

$$\omega_u=\frac{\omega_h}{\eta_b}=\frac{2\pi f_h}{\eta_b}=\frac{2\pi 15\cdot10^6}{1.84}=51.22\ \text{Mrad/s}$$

Since $\omega_n = 1/RC$ then the value of the loading resistor is

$$R=\frac{1}{\omega_n C}=\frac{1}{51.22\cdot10^{6}\cdot27\cdot10^{-12}}=723.1\Omega \qquad (4)$$

The value of the inductance is

$$L= 0.414 \ R^2C=0.414\cdot723.1^2\cdot27.10^{-12} = 5.866\mu H$$

The coil self-capacitance plus strays at the coil should be

$$C_L=0.35C=0.35\cdot27\cdot10^{-12}=9.45pF$$

The poles and zeros are

$$S_{1,2p}=-\sigma_{1p}\pm j\omega_{1p}$$

and

$$S_{3p}=\sigma_2,\ S_{1,2z}=-\sigma_{1z}\pm j\omega_{1z}$$

where

$\sigma_{1p} = 0.850\,\omega_n = 0.85\cdot51.22\cdot10^6 = 43.54$ Mrad/s
$\omega_{1p} = 1.577\,\omega_n = 80.78$ Mrad/s
$\sigma_{2p} = 2.125\,\omega_n = 108.85$ Mrad/s
$\sigma_{1z} = 1.412\,\omega_n = 72.32$ Mrad/s
$\omega_{1z} = 2.197\,\omega_n = 112.53$ Mrad/s

The phase response is, according to equation (2).

$$\varphi(\omega)=\tan^{-1}\frac{\omega-112.53\cdot10^6}{72.32\cdot10^6}+\tan^{-1}\frac{\omega+112.53\cdot10^6}{72.32\cdot10^6}$$
$$-\tan^{-1}\frac{\omega-80.87\cdot10^6}{43.54\cdot10^6}-\tan^{-1}\frac{\omega+80.87\cdot10^6}{43.54\cdot10^6}$$
$$-\tan^{-1}\frac{\omega}{108.85\cdot10^6}$$

The result is either in degrees or in radians, depending on how the $\tan_{-1}$ function is programmed.

With formula (3) we calculate the envelope-delay

$$\tau_e(\omega)=\frac{72.32\cdot10^6}{(72.32\cdot10^6)^2+(\omega-112.53\cdot10^6)^2}$$
$$+\frac{72.32\cdot10^6}{(72.32\cdot10^6)^2+(\omega+112.53\cdot10^6)^2}$$
$$-\frac{43.54\cdot10^6}{(43.54\cdot10^6)^2+(\omega-80.78\cdot10^6)^2}$$
$$-\frac{43.54\cdot10^6}{(43.54\cdot10^6)^2+(\omega+80.78\cdot10^6)^2}$$
$$-\frac{108.85\cdot10^6}{(108\cdot10^6)^2-\omega^2}\ \text{[seconds]}$$

To apply the formula for frequency response the figure $\omega_n = 51.22$ Mrad/s and the variable frequency ω, also in Mrad/s, should be put in the equation for the frequency response of the circuit (e).

EXAMPLE 2

An m.f.e.d.-type amplifier stage should be designed with a three pole T-coil circuit (type h) with the following data:

total stray capacitance $c_{tot}=21$ pF
desired risetime $\tau_r=20$ ns

We first calculate the value of the loading resistor on the basis of the risetime improvement factor η_r.

$$\eta_r=\frac{\tau_H}{\tau_r}=\frac{2.2T}{\tau_r}=\frac{2.2RC}{\tau_r}$$

and out of this

$$R=\frac{\eta_r\tau_r}{2.2\,C_{tot}}=\frac{2.78\cdot20\cdot10^{-9}}{2.2\cdot21\cdot10^{-12}}=1203\Omega$$

The time constant is

$$T=RC_{tot}= 1203\cdot21\cdot10^{-12} = 25.26\text{ ns}$$

The next step is the calculation of both stray capacitances C_i and C.

$$C_i=0.28\cdot C_{tot} = 0.28\cdot21 = 5.88\text{ pF}$$
$$C = C_{tot}-C_i = 21-5.88 = 15.12\text{ pF}$$

The T-coil bridging capacitance is

$$C_b= 0.119C = 0.119\cdot15.12 = 1.80\text{ pF}$$

The value of the T-coil inductance is

$$L=R^2C = 1203^2\cdot15.12\cdot10^{-12} = 21.88\,\mu H$$

The coupling factor between both halves of the centre-tapped T-coil is (from the Table).

$$k=0.35$$

If the coil is tightly wound as a single-layer cylindrical solenoid this requires a length-to-diameter ratio of 0.49[16]. The easiest way to achieve such a coupling factor with a more reasonable (greater) length-to-diameter ratio is to use a suitable coil form with an adjustable h.f. ferrite core to increase the coupling. (Smaller length-to-diameter ratios which are mandatory with the (e)-type circuits can be achieved if both halves of the T-coil are in the form of a flat spiral on each side of a printed circuit board, where the board thickness sets the coupling factor.)

The poles are

$$S_{1,2p}=-\sigma_{1p}\pm j\omega_{1p},\ S_{3p}=-\sigma_{2p}$$

where

$\sigma_{1p} = 2.886/T = 2.886/25.26\cdot10^{-9} = 114.24$ Mrad/s
$\omega_{1p} = 2.752/T = 108.93$ Mrad/s
$\sigma_{2p} = 3.645/T = 144.30$ Mrad/s

Now we can calculate the frequency response with the aid of formula (1). As we have no zeros, the first square root is replaced by the number one and we get

$$F(\omega)=\frac{V_o}{I_i}$$
$$=\sqrt{\frac{(114.24^2+108.93^2)^2\ 144.30^2}{[114.24^2+(\omega-108.93)^2]\,[114.30^2+(\omega+108.93)^2](144.30^2+\omega^2)}}$$

Since we entered poles in Mrad/s, the variable frequency should also be in Mrad/s. In order to show better the analogy with formula (1) we did not cancel the square and the square root in the numerator.

If a more accurate plot than the curve H in Fig.3 is desired, the value T = 25.26 ns should be put in the formula for the step response of the circuit h and the variable t should be entered in nanoseconds as well to get the desired step response.

Acknowledgments
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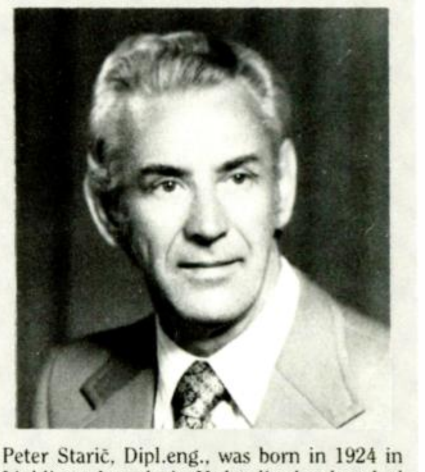
References

1. C. R. Battjes, Amplifier Risetime and Frequency Response, (class notes), Tektronix, Inc. Beavertone, Ore., 1969.
2. J. Bednařík & J. Danek, Obrazove zesilovače pro televisis a měřici techniku, Statní nakladatelství technicke literatury, Prague, Czechoslovakia, 1957, (in Czech).
3. G. Valley & H. Wallman, Vacuum Tube Amplifers, vol. 18 of the Radiation Laboratory Series, McGraw-Hill, New York, 1948.
4. S. Butterworth, On the Theory of Filter Amplifiers, *Experimental Wireless & Wireless Engineer*, vol. 7, 1930, pp. 536-541.
5. W. E. Thomson, Networks with Maximally Flat Delay, *Wireless Engineer*, vol. 29, 1952, pp. 256-263.
6. L. Storch, Synthesis of Constant-time-Delay Ladder Networks Using Bessel Polynomials, *Proceedings of the I.R.E.*, vol. 42, 1954 pp. 1666-1675.
7. A. B. Williams, Electronic Filter Design Handbook, McGraw-Hill, New York, 1981.
8. G. Doetsch, Anleitung zum praktischen Gebrauch der Laplace-Transformation und Z-Transformation, 5th Edition, Oldenburg-Verlag, Munich, 1985, (in German).
9. O. Follinger, Laplace- und Fourier-Transformation, AEG-Telefunken AG, Berlin, 1982, (in German).
10. M. E. Van Valkenburg, Introduction to Modern Network Synthesis, John Wiley, New York, 1964.
11. A. I. Zverev, Handbook of Filter Synthesis, John Wiley, New York, 1967.
12. F.A. Muller, High-Frequency Compensation of RC Amplifiers *Proceedings of IRE*, 1954, pp. 1271-1276.
13. G. J. A. Bird, Design of Continuous and Digital Electronic Systems, McGraw-Hill, New York, 1980.
14. G. B. Braude et al., The Calculation of a Combined Circuit for the Correction of Television Amplifiers (in Russian), *Radiotekhnika*, T. 4, No 6, Moscow, 1949.
15. L. J. Giacoletto, Electronic Designer's Handbook, Second Edition, McGraw-Hill, New York, 1977
16. F. W. Grover, Inductance Calculations, Inst. Soc. of American, PO Box 12277, Research Triangle Park, N.C. 27709.



Peter Starič, Dipl.eng., was born in 1924 in Ljubljana, Jugoslavia. He has lived and worked there, except for three years at Tektronix, Beaverton, Ohio. He now works at the Jozef Stefan Institute in Ljubljana on the design of electronic equipment for mass spectrometry.

Feedback

J. W. offers some positive remarks on a negative subject.

JOULES WATT

In a Giles cartoon some years ago, "Chalkie", the schoolmaster character, was considering the mini-scandal going on at the time concerning children turning up to school drugged with tranquillizers. On the classroom wall in a glass case, a mounted, bent-handled cane had a caption, "Old fashioned tranquillizer", and I realised that this instrument had for centuries been intended to act in a "negative-feedback control-loop" to curb unruly behaviour. In fact, according to earlier published reports, the theory goes back to the published account, "spare the rod and spoil the child".

Closer to home, Newton's Third Law – you know the one – "for every action there is an equal and opposite reaction", shows a familiar example of what amounts to 100% feedback.

Every radio well illustrates negative feedback, even if there is no feedback circuitry within it: your brain and muscular activity (motor system . . .) complete the control loop while tuning in a station. As the station becomes audible, your brain processes the information and activates your fingers on the tuning knob, thus making you pass right through the tuning point. This generates an error signal while you move into the other sideband (you hear the distortion), so that you rapidly reach the optimum position by smaller and smaller "wobbles" each side. All this takes a second or two, usually without conscious realisation.

DOING IT ELECTRONICALLY

Within systems, such as audio amplifiers, the control loop feeds back a sample of the output signal and compares it with the input, using the result of the comparison to reduce errors. At least, this is true for *negative* feedback.

Such electronic feedback loops often carry out the radio tuning job by means of an automatic frequency control (a.f.c.) system. In fact, modern receivers contain a surprising amount of automatic control circuitry: other than a.f.c. there might be frequency synthesizers using phase-locked loops (p.l.ls) and certainly automatic gain-control circuits (a.g.c.).

But we usually meet negative feedback in its direct raw state within amplifier systems, as I mentioned. My purpose here is to describe how it affects the performance of the amplifier and why we use it.

APPLYING THE FEEDBACK

In the case of amplifiers, the question that I discussed earlier[2] arises – what are we amplifying? In the present context, the answer to that question shows the way in which to apply the feedback: whether it should be "voltage" or "current" feedback and whether it should be in shunt or series, and so on. At the start, you will find useful a general discussion that applies to any configuration. This develops the principles and shows the effects of feedback without too much detail involving actual circuits.

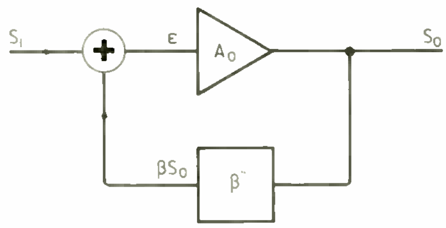


Fig.1. All feedback systems comprise a loop where a fraction of the output goes back to the input and is added there to produce an error signal.

Any amplifier amplifies, so that A_o in Fig. 1 represents such a stage giving an output signal S_o from a signal ϵ applied to its input terminals. We call the amplification A_o the *open-loop gain* for a reason that becomes obvious in a moment.

The "β" block has S_o as its input and feeds a fraction βS_o out to the summing point (+) where it adds to the input signal S_i, the result of this addition now resulting in ϵ, mentioned above.

The whole system operates in a closed loop. The rate at which the output changes with the input, or ratio S_o/S_i, gives the overall amplification. We term this quantity the *closed-loop gain*, and it will certainly differ from the open-loop gain. The signal going into the amplifier terminals, composed as it is from the main input S_i and the fed-back fraction βS_o, acts as an "error" signal, hence the usual symbol ϵ for it. You can see the operation of a feedback loop such as this by following through the simple analysis.

$$\begin{aligned} S_o &= A_o\epsilon \\ \epsilon &= S_i + \beta S_o \\ \therefore\quad S_o &= A_o S_i + A_o\beta S_o \\ \therefore\quad \frac{S_o}{S_i} &= \frac{A_o}{1-\beta A_o} = A_c \end{aligned}$$

in which we often write βA_o = T. Logically, A_c stands for *closed*-loop gain. The symbol T measures the total gain right round the loop. In other words, if you break the loop and consider going through the gain A_o and back to the break via "β", then T follows as defined. If this loop gain T >> 1, then the closed-loop gain of the amplifier with feedback becomes very nearly equal to $1/\beta$, a result independent of the open loop gain, A_o.

In practice, "β" usually contains passive components only, so that the gain of the system is now very well defined and stable, unlike A_o which drifts and varies with temperature and supply voltage.

From the feedback equation derived above, you will notice the denominator could become zero if A_o and β are positive numbers. This condition illustrates *positive* feedback and T=1 now gives the condition for the onset of oscillation. As $A_c \rightarrow \infty$ the circuit now supplies its own input and in oscillator parlance the Barkhausen condition applies. In the case of the negative feedback we are discussing, either A_o or β must provide a signal inversion, so that $-\beta A_o$ becomes a positive quantity and the denominator certainly cannot now become zero. In fact, if this condition applies and T is large, then we see that A_c might be considerably less than A_o. This means negative feedback reduces the gain of an amplifier stage, as you might have inferred already.

Another way of saying this, as well as seeing what happens to the "error" signal ϵ is to write

$$\begin{aligned} \epsilon &= S_i + \beta S_o \\ &= S_i + \frac{\beta A_o S_i}{1-\beta A_o} \end{aligned}$$

which tidies up to

$$S_i \frac{1}{1-\beta A_o}$$

This shows that if $-\beta A_o >> 1$, $\epsilon << S_i$. Therefore, a large amount of negative feedback makes the "error" signal ϵ very small. Also,

$$\frac{S_o}{S_i} = \frac{\beta A_o}{1-\beta A_o} = \frac{T}{1-T}$$

showing that, with large feedback, the input signal and the fed-back signal become very nearly equal. This means that S_o is a replica of the input S_i. If $|\beta| << 1$, then S_o turns out to be a precisely amplified version of S_i – which is what we hoped negative feedback would yield.

As I mentioned, many high-gain amplifiers possess a large, but unstable A_o. One of the claims the advocates of negative feedback make is that it reduces gain fluctuations.

Consider dA_c/dA_o, which is equal to

$$\frac{(1-A_o\beta)+\beta A_o}{(1-\beta A_o)^2} = \frac{1}{(1-\beta A_o)^2}$$

so that $\Delta A_c = \Delta A_o/(1-\beta A_o)^2$, from which you can see that the gain drifts really do become small, because $-\beta A_o >> 1$. (Remember, one or other of A_o or β must be a negative quantity.) Writing this out as a fractional change in A_c compared to that in A_o shows up the improvement even better.

$$\frac{\Delta A_c}{A_c} = \frac{1}{1-\beta A_o} \cdot \frac{\Delta A_o}{A_o}$$

This means that, for example, if $\Delta A_o/A_o$ is, say, 12% and βA_o is – 150, then your closed loop gain only changes by 0.08%.

DISTORTION

One of the earliest uses of negative feedback in amplifiers was to reduce the non-linearity distortion in large-signal stages. You might remember that such distortion occurs when large signal swings move the operating point so far along the dynamic curve of active devices (thermionic valves originally), that it leaves the linear part and enters the region of curvature, rather like the situation in Fig.2.

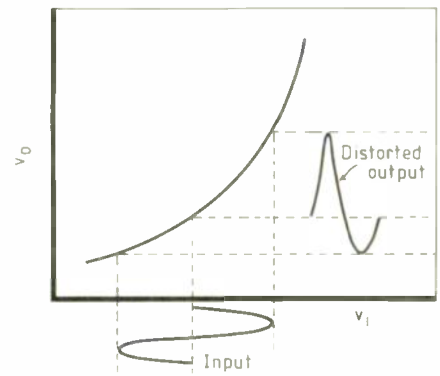


Fig.2. Curved transfer characteristics like this produce a distorted version of the signal at the output. In this example, the distortion appears mainly as second harmonic.

Suppose the added distortion signal appears quite late in the chain of stages making up the amplifier. This will certainly be true if only large signal swings are in danger of entering the non-linear region of the transfer characteristics. The schematic of this, shown in Fig.3, enables us to introduce the distortion signal somewhere along

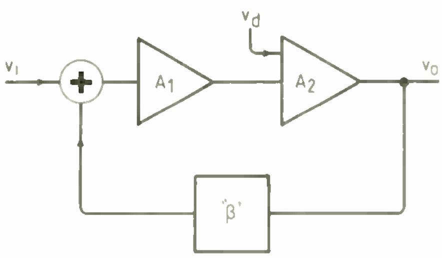


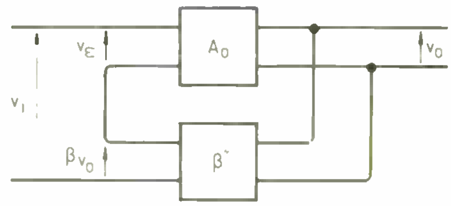
Fig.3. The distortion in an amplifier chain arises mainly towards the back end. When fed back negatively, it becomes much reduced by cancellation.

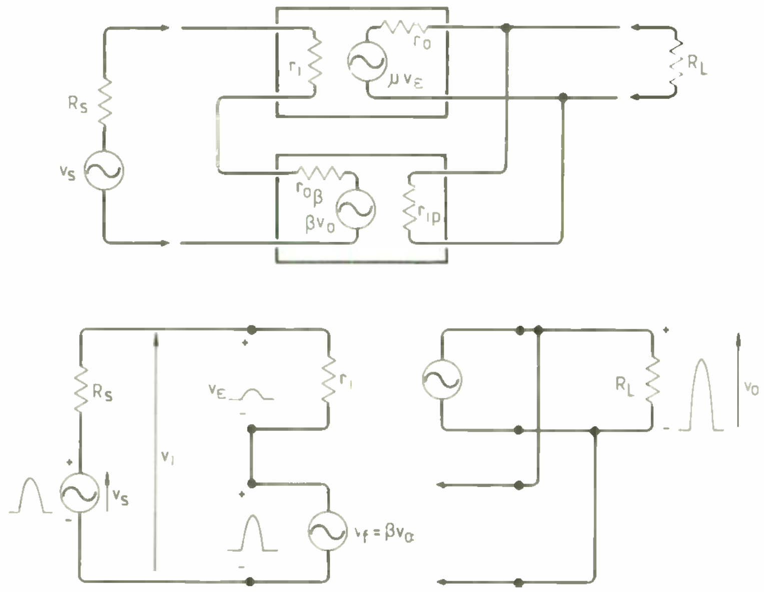
the chain such that a relatively small remaining amplification amounting to A_2 times, gives it a boost. The total signal, $v_\epsilon A_1 A_2 + v_d A_2$ appears at the output. The usual fraction of this goes round and adds at the input so that, exactly as before, the final result is

$$v_o = \frac{A_1 A_2 v_i}{1 - \beta A_1 A_2} + \frac{A_2 v_d}{1 - \beta A_1 A_2},$$

showing that, although the gain goes down by the expected factor, so does the distortion amplitude. As this was amplified by the reduced amount, A_2 only, this means an improvement because we can make up the loss of signal gain in the early low distortion stages.

Fig.4. In (a) is a typical voltage amplifier with shunt-sampled, series-input voltage feedback. In (b), the load R_L and the signal source v_s are shown, together with the internal equivalent networks in the amplifier and feedback blocks. The ideal blocks appear as in (c), which also gives an indication of the way a positive signal pulse appears in different parts of the system.





WHAT IS FED BACK?

Just as we found a number of meanings to "amplification"[2], so there is a number of ways to take the feedback sample and combine it with the input. If you take a sample of the signal voltage appearing across the output terminals and feed it back in series with the input voltage to the amplifier, you get an example of what older treatises called "voltage" feedback. The more modern terminology, based on the way we make the connections, describes things better.

Series-shunt feedback. The example I mentioned above appears in Fig.4. You can see clearly the series input connection and the shunt sampling across the output terminals. The feedback network "β", should load the amplifier by the smallest amount possible. This network does tend to load real amplifiers, because of its passive nature as a resistive attenuator, but we can write the conditions for negligible loading in 4(b) as $r_{i\beta} >> r_o$ and $r_{o\beta} << r_i$.

Under the further conditions that $r_o << R_L$ and that $r_i >> R_s$, in other words, that we have a "good" (ideal) voltage amplifier, we have,

$$v_o = \mu v_\epsilon$$
$$v_i = v_s$$
$$v_\epsilon = v_i - \beta v_o$$

$$\therefore \quad \frac{v_o}{v_i} = \frac{\mu}{1 + \beta\mu}$$

The "shape" of the equation we have obtained, agrees with the general result obtained earlier, except for the plus sign in the denominator. In fact, this slight "discrepancy" shows we have obtained the correct feedback phase by means of a third possibility – by *subtracting* the sampled fed-back component, instead of adding it, as carried out earlier. The series connection does this automatically. By Kirchhoff's voltage law, we have in 4(c)

$$v_i = v_\epsilon + v_f,$$
$$\therefore \quad v_\epsilon = v_i - v_f,$$

which shows the subtraction clearly. There is one point you might note. This last discussion explains why some books contain the minus sign in the denominator, while others use the plus. The authors either combine the signals by *adding*, as I did earlier, or else use a *subtractor* instead.

The "error" voltage, v_ϵ across r_i, now much smaller than v_i, drives little current into r_i. This plausible thinking shows that the effective input resistance "looks" as though it has been increased.

Similarly, the shunt feedback connection at the output indicates that any fall in signal amplitude there (from say, connecting smaller load resistors) proportionally reduces v_f. This increases the value of v_ϵ at the internal amplifier terminals, so raising v_o again. You can see that such action appears to make r_o have little effect, in other words, r_o appears much smaller than without feedback.

The resistances. What we have managed to show amounts to saying that the *inner* voltage gain, v_o/v_i, receives the full stabilizing effect of this kind of feedback.

How does the *outer* voltage gain (v_o/v_s) fare? From the input potential divider effect you can write straightaway that

$$v_i = \frac{r_i}{r_i + r_s} v_s$$

Therefore, if $r_s \sim r_i$, the v_i depends on r_i and, as this might not be stable, the feedback fails to cope. For the full improvement, we should make the source resistance low with respect to r_i.

Suppose the input voltage v_i sets up an input current i_i, given by v_ϵ / r_i. Again, $v_o = \mu v_\epsilon$ and $v_i = v_\epsilon + v_o$. From this,

$$v_i = v_\epsilon (1 + \beta\mu)$$

$$\text{So that } i_i = \frac{V_i}{r_i} \cdot \frac{1}{1 + \beta\mu}$$

$$\therefore \quad \frac{v_i}{i_i} = r_{if} = r_i(1 + \beta\mu)$$

$$= r_i (1 + T)$$

Indeed, the feedback has greatly increased the effective input resistance, which makes the requirement $R_s << r_i$ I mentioned above much easier to achieve.

You can find the effect of the feedback on r_o by short-circuiting the input terminals and applying a test voltage, v_t, across the output, as in Fig.5.

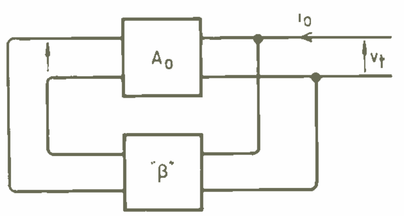


Fig.5. By shorting the input terminals and feeding a signal into the output port, we obtain the output resistance.

Now we have,

$$i_o = \frac{v_t + \mu\beta v_t}{r_o}$$

$$\therefore \quad r_{of} = \frac{v_t}{i_o} = \frac{r_o}{1 + \mu\beta}$$

which, of course, means that the effective output resistance r_{of}, looks much smaller than the original, r_o.

These arguments shows that series-shunt feedback applied to a voltage amplifier makes it approach the ideal more closely – the input resistance becomes greater and the output resistance falls.

Familiar example. Emitter followers possess a voltage gain of one – or more correctly, slightly *less* than one. You would think that such a performance in a voltage amplifier would be next to useless, but the impedance changing properties of the 100% negative feedback inherent in the circuit make it so useful that the effect on the gain becomes of secondary importance.

Of course, the emitter follower is a decendent of the cathode follower, a famous thermionic valve circuit. W. A. Atherton pointed out[4] that the genius of A. D. Blumlein gave us the cathode follower, but sadly he never lived to see the solid state version of one of his remarkable contributions.

The performance of the emitter follower requires us to derive the usual equivalent circuit[3]. Figure 6 shows a typical example. We can use the common-emitter para-

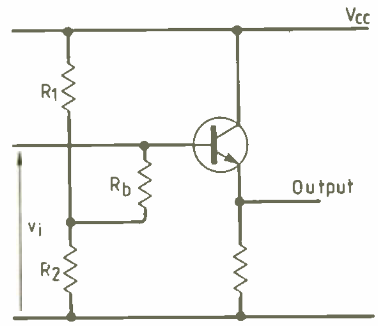
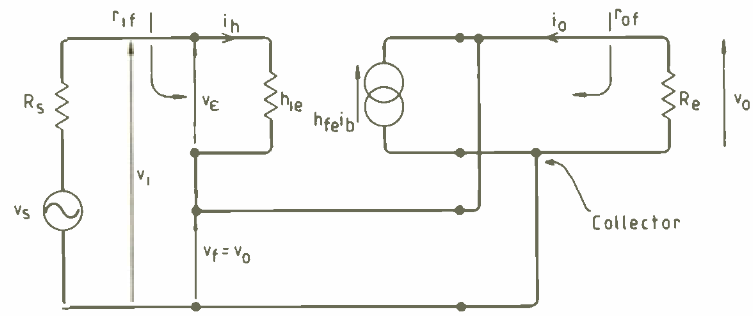


Fig.6. This is a standard emitter-follower circuit, where R_1, R_2 and R_b set a suitable bias point.

Fig.7. A careful use of the common-emitter h parameters results in this equivalent circuit for the emitter follower. Notice the series – shunt feedback configuration arises naturally.



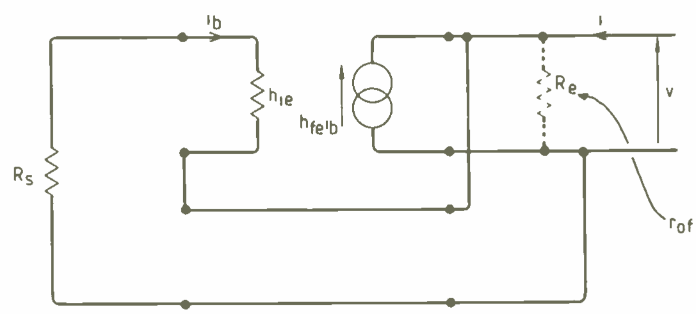


Fig.8. As in Fig.5, short the input generator to yield the output resistance.

meters, although enthusiasts prefer using the common-collector parameters (common-collector circuit is the other name for the emitter follower), but using the common-emitter parameters brings out the analysis as an example of a feedback circuit.

Notice that the equivalent circuit in Fig.7 has accomplished this. You can see clearly the series input connection and the shunt output sampling – agreeing with the general voltage amplifier I discussed above. It looks as if β will turn out to be 1, as it must for 100% feedback. If the gain can be written 1/β, as before, then A becomes ~ 1 as we expect for this circuit.

Finding the gain. From Fig 7,

$$v_\epsilon = v_i - v_o$$

$$\therefore \quad i_b = \frac{v_\epsilon}{h_{ie}} = \frac{v_i - v_o}{h_{ie}}$$

$$\text{and } v_o = i_o R_e = i_b h_{fe} R_e$$

$$\text{so that, } v_o = \frac{h_{fe} R_e (v_i - v_o)}{h_{ie}}$$

We need the ratio v_o/v_i for the closed-loop gain, and can get it by transposing the last equation,

$$A_v = \frac{v_o}{v_i} = \frac{\dfrac{h_{fe}R_e}{h_{ie}}}{1 + \dfrac{h_{fe}R_e}{h_{ie}}} = \frac{A_o}{1 + \beta A_o}$$

This shows $\beta = 1$ and $A_o = h_{fe} R_e / h_{ie} = g_m R_e$ because for a bipolar transistor, h_{fe}/h_{ie} yields its g_m.

Input resistance. The input resistance of the amplifier with large-value base-bias resistors and no feedback, simply amounts to h_{ie}. You can look at the above equations to see what happens to the input resistance with feedback applied.

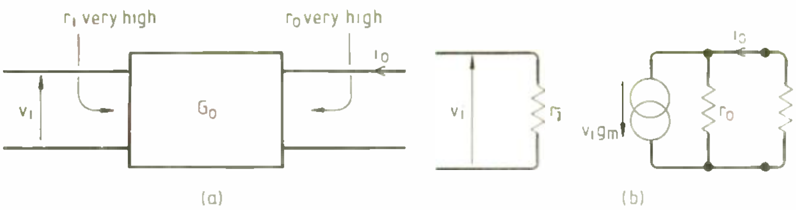
$$i_b = \frac{v_i - i_b h_{fe} R_e}{h_{ie}}$$

$$\therefore \quad v_i = i_b (h_{ie} + h_{fe} R_e)$$

$$\text{and} \quad \frac{v_i}{i_b} = r_{if} = h_{ie} + h_{fe} R_e$$

The second term might be many times larger than h_{ie} with reasonably large value for R_e and high-gain transistors. Notice the feedback does what we expect for the series input connection, it raises the input resistance.

Output resistance. Looking back into the emitter, without R_e, gives the circuit output resistance. Because we have neglected the transistor output conductance parameter h_{oe}, on account of its shunting effect being so small, a result of the form ∞/∞ turns up if we try to calculate the output resistance looking straight into the emitter. To overcome this hiccup, *include* R_e in the calculation then let it go to infinity in the equation –



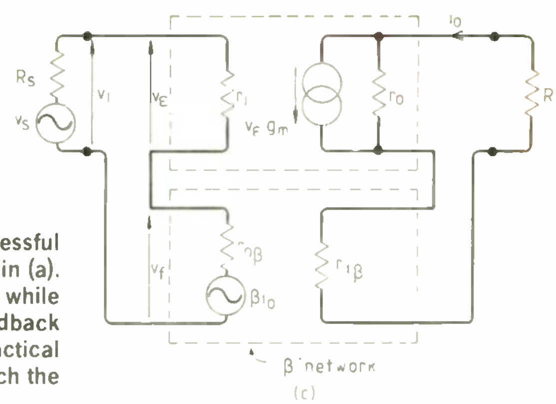


Fig.9. The conditions for a successful transconductance amplifier appear in (a). Its equivalent circuit is shown in (b), while (c) illustrates the series – series feedback connections which make the practical transconductance amplifier approach the ideal even more closely.

and the result follows.

As before, remove the signal voltage at the input. But for a little variety, leave the generator resistance R_s in circuit this time. Apply a voltage v across the output terminals, as in Fig.8. By doing this, we establish a current i so that by taking v/i we obtain r_{of}.

$$i_b = -\frac{v}{R_s + h_{ie}}$$

and at the output,

$$v = (i_b + i_b h_{fe}) R_e$$

Substitute for i_b,

$$\frac{v}{R_e} = i - \frac{v h_{fe}}{R_s + h_{ie}}$$

$$v\left(\frac{1}{R_e} + \frac{h_{fe}}{R_s + h_{ie}}\right) = i$$

$$\frac{v}{i} = r_{of} = \frac{R_e(R_s + h_{ie})}{R_s + h_{ie} + R_e h_{fe}}$$

for R_e present.

Now let $R_e \to \infty$ (after dividing it into top and bottom); therefore, looking into the emitter,

$$r_{of} = \frac{R_s + h_{ie}}{h_{fe}}$$

and although low (h_{fe} is a large number), it depends on the source resistance R_s. You might remember this resistance should be small in any case for a voltage amplifier. If you make it small enough with respect to h_{ie} – one way of doing this is to short it out, as we have been doing in previous examples – then,

$$r_{of} = \frac{h_{ie}}{h_{fe}} \text{ which is } \frac{1}{g_m} \text{... very small.}$$

Therefore, you see that emitter followers perform according to the theory. I have rather sneakily glossed over what happens to the input current, after it flows out of the bottom of h_{ie}. For a complete discussion, you have to consider the effect of this current in the output circuit, where so far no cognisance has been taken of it. Fortunately, the only effect when we include it in deriving the results, is that h_{fe} increases to $(h_{fe} + 1)$ in all the equations. Because for modern transistors, h_{fe} might be some hundreds, very little error occurs by neglecting the 1 in comparison to h_{fe}.

FEEDBACK IN OTHER AMPLIFIERS

Analysing one further amplifier circuit with negative feedback applied should convince you that, as well as reducing gain, drift and distortion, we can 'doctor' the terminal resistances by judicious use of the correct feedback connections. You should also be able to go on to treat all the other amplifier possibilities confidently as an exercise.

Consider the transconductance amplifier, where the 'gain' is now the transfer function,

$$G_m = \frac{i_o}{v_i}$$

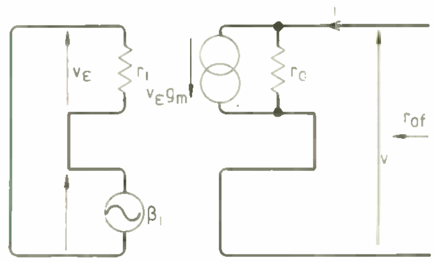


Fig.10. Once again, the trick of shorting the input gives the output resistance.

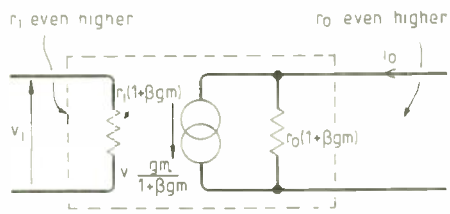


Fig.11. We can show the improvement that feedback has produced by re-drawing the amplifier block with the modified parameters inserted. Both resistances have been greatly increased in this example.

A good transconductance amplifier requires r_i to be high; at least it requires $r_i >> R_{source}$ (ref.2). At the same time, we require r_o to be large, that is, $r_o >> R_L$.

The earlier discussion showed how we can increase the effective input resistance; we can do it by using a *series* input connection. On the basis of a similar argument, you might try a *series* connection at the output to see if it increases r_o, a condition desirable for transconductance amplifiers. This gives the series-series feedback circuit that Fig.9 shows. A series connection at the output naturally samples the output current.

We still need a feedback voltage at the input, so the feedback network now has the job of producing this voltage from the current sample, as well as setting the amount of feedback. The Norton-type equivalent circuit arises in modelling the output of a transconductance amplifier. Figure 9 illustrates these points for the amplifier and "β" networks, together with conditions for a good approximation to the ideal.

Closed-loop gain and terminal impedances. You can write straightaway that,

$$v_\varepsilon = v_i - \beta i_o$$

and

$$i_o = g_m v_\varepsilon$$

so that,

$$i_o = g_m(v_i - \beta i_o)$$

$$\therefore \quad i_o(1 + g_m\beta) = g_m v_i$$

and with some satisfaction, we get the final result and see that it has the same "shape" again.

$$G_c = \frac{i_o}{v_i} = \frac{g_m}{1 + \beta g_m}$$

where G_c is the closed loop gain.

Notice that the effect on the input resistance remains as before (we have not changed anything). You can find the output resistance by the same trick – reduce the input-generator voltage to zero, but this time pass a current i into the output terminals, Fig.10.

Now $v_\varepsilon + \beta i = 0$ at the input, and from Ohm's Law the voltage v that appears across the output terminals is,

$$v = (i - v_\varepsilon g_m) r_o$$
$$= (i + i\beta g_m) r_o$$

by replacing v_ε with $-\beta i$.

Finally,

$$r_{of} = \frac{v}{i} = r_o(1 + \beta g_m)$$

$$= r_o(1 + T),$$

where $T = \beta g_m$

Notice that g_m and therefore β possess physical dimensions in this circuit, but T is always dimensionless in all the feedback equations of this type. The output resistance has indeed gone up. The closed-loop amplifier now looks like that in Fig.11. Therefore, negative feedback has made it a better transconductance amplifier, but with reduced gain.

References

1. Proverbs, chapter 13, verse 24, "If a father spares the rod, he hates his son...".

2. Joules Watt "Voltage or Current" *EWW* 93, p477, May 1987.

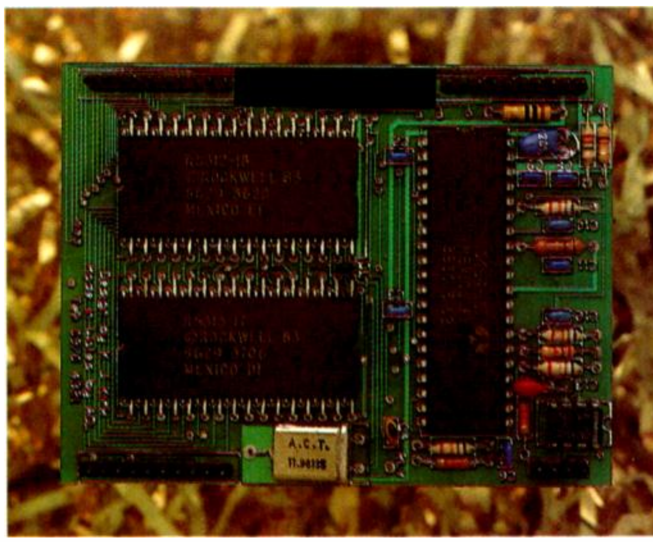
3. W.A. Atherton, Pioneers, *EWW* p184, February, 1988.

4. Joules Watt "Equivalent Circuits" *EWW* 93, p1204, December 1987.

Designing a high-speed modem

Practical aspects of an intelligent autodialling modem which offers full duplex communications at speeds up to 2400bit/s.

KEVIN J. KIRK



Plug-in module carrying Rockwell's R2424 modem chip set.

Last month I described the requirements for a modem which is intended to meet the recommendations of CCITT and so to be compatible with other commonly available modems. Many of the standards governing the use of modems on public telephone circuits run by British Telecom and Hull Telecom are based on CCITT recommendations and it therefore seems reasonable to follow these recommendations in our design. However, to enable readers overseas to adapt the design for their local PTT network we must be able to make changes regarding carrier levels, guard tones and so on. These changes must be fairly easy to make and so are better implemented in software rather than hardware.

Further, although this design is not proposed as a definitive product, being intended primarily for experimental and learning purposes, it must be capable of being driven from available software, including public domain software. It therefore uses the 'AT' or 'Hayes' command set and so will work with the vast majority of Hayes-compatible software such as Crosstalk, Datatalk, Transend etc.

Other features of this modem include automatic dialling using pulse repetition (or Strowger 'loop disconnect' dialling, still in use by British Telecom after nearly a century) or tone dialling (dual-tone multi-frequency), again from within the preferred software; and a call progress monitor (a loudspeaker) to enable the call to be monitored by the operator, again under software control.

The design should, if put forward, obtain BABT approval if it were manufactured under controlled conditions and were to meet certain layout specifications. However, it is not practical for individual readers to apply personally for production inspection and so BABT approval obviously is not available to them. The modem will work on public lines; but you use it at your peril, as the network operator could confiscate it and the attached terminal (though this rarely happens, except possibly in Hull).

Many modem chips and chip sets can be configured to fulfil our requirements. However, the most comprehensive set so far available is the R2424 from Rockwell. Before describing the set's many virtues, it is appropriate to point out that it suffers from a couple of problems.

The first is an operational one, in that after dialling the filters are turned to wide-band mode and will detect any signal above −43dB as carrier. Therefore the modem may go on line with the unobtainable tone – hence the requirement for a call progress monitor loudspeaker. The second problem is one of power: this device set is very thirsty, drawing a good 750mA. Consequently it gets warm. If the modem is built into the same box as the power supply, heat problems could arise (as one well-known modem manufacturer has found to his cost). On tests though, most PCs have coped with this pretty happily.

One other small problem is in the choice of processor to drive the set (the 6501Q). This device seems to have a peculiar interrupt structure and can hang up on nested interrupts. So the advice is, don't mess with the interrupt driver software.

Apart from these niggles, the Rockwell device set is excellent. It allows full software control of all modem functions besides doing much of the hard work in the hand-shaking after going on line (unlike many of the single devices such as those by Sierra, AMI or Thomson, which require external control).

Rockwell's set is based on three chips. The first two are 16 bit d.s.p. chips, one for transmit and one for receive, which provide all the modem functions right through to modulation. An analogue processor completes the set, providing analogue-to-digital conversion, the data access arrangement output (telephone line interface) and control signals. The modem devices are accessed using dual-port rams resident within the d.s.p. chips. These rams have a capacity of eight bits and are 16 bytes long. If you have ever done any dual processor work you will know that this is the ideal method of interchanging control and data information: it lets you read what you have written to verify that you are getting through. Here the only drawback is that the timing required to access the rams is a bit awkward,

SPECIFICATION

The most important performance criterion is that the unit must meet the standards laid down by CCITT. So the principal specifications of our unit are:

- 1200bit/s full duplex (2400bit/s on V.22*bis* unit) via the public network.
- Channel separation by frequency division.
- D.p.s.k. modulation of 600 baud carrier.
- Integral scrambler.
- Integral automatic adaptive equalizer.
- Fixed compromise equalizer.
- Full test facilities.
- Bell 212A capability.
- Software-controlled level and guard tone generation.
- Fallback on noisy lines to 600 baud d.p.s.k. or to 300 baud f.s.k.
- Automatic detection of terminal baud rate.
- Capability of configuration and operation on leased lines.
- Automatic selection of odd, even or no parity.
- Automatic selection of seven or eight bit words.
- Automatic selection of one or two stop bits.

with read pulses going 'not valid' before chip select lines and register select lines. The logic array takes care of this, though, using the inverse of the 6501 internal clock in addition to the normal memory mapping.

A point to note is that there are two methods of controlling the V.24 functions of the devices: either serial mode using hardware lines, or parallel mode using the registers. This is fine except for two annoying features. One is that you cannot pick and mix the signals with some hardware and some software signals, which limits flexibility. Secondly, the unit powers up in serial mode which is the opposite of what logic dictates. This would not matter if the devices powered up in a CCITT logical state (output levels preset etc.): by using a simple bank of dil switches we could then configure the unit to the mode we required since this would allow us to design a dumb modem which would be more appropriate to many tasks. One point I should like to make to any Rockwell design engineer who happens to read this article is this: why not allow the data itself to be read and written to in *parallel* via the registers, thus saving an extra uart in high speed data manipulation functions (such as cryptography or complex compression techniques)? A modem could then be connected simply to any bus and could be treated like any other peripheral.

Register maps for the transmitter and receiver interface chips are given by Rockwell on page 76 of the Designer's Guide.

PROCESSOR

The 6501 control processor was chosen because it supplies the correct timing signals for communication with the device set. It also has a multitude of i/o control lines, a full duplex serial port and is well supported by Rockwell.

Since much of the logic in the unit is primarily to provide serial signal routing and to provide processor i/o access timing, a single logic array (IC_2) is used in place of six or so discrete t.t.l. packages.

The serial port is based on standard RS-232 driver and receiver chips. Note that the modem has a speed output pin to indicate to the terminal whether it is in high-speed mode.

On the line interface side it was decided to use an inductor and a.c.-coupled line transformer combination. This was because the line transformer, being a miniature type, is incapable of sinking the 20mA or so required for line holding. An inductor was chosen in preference to a semiconductor gyrator as it can be used on clean lines without the 'wetting' voltage required on a semiconductor unit to forward-bias the rectifiers. This is ideal for some leased lines and for private circuits. However it may mean that voltage rise-times in dialling may exceed national standards and so two zeners may be required to shunt the inductor. To limit back-e.m.f. from the inductor and to provide some protection against line overvoltage a v.d.r. is recommended and is mandatory in some countries.

A telephone may be used in parallel with the modem and so a second relay has been

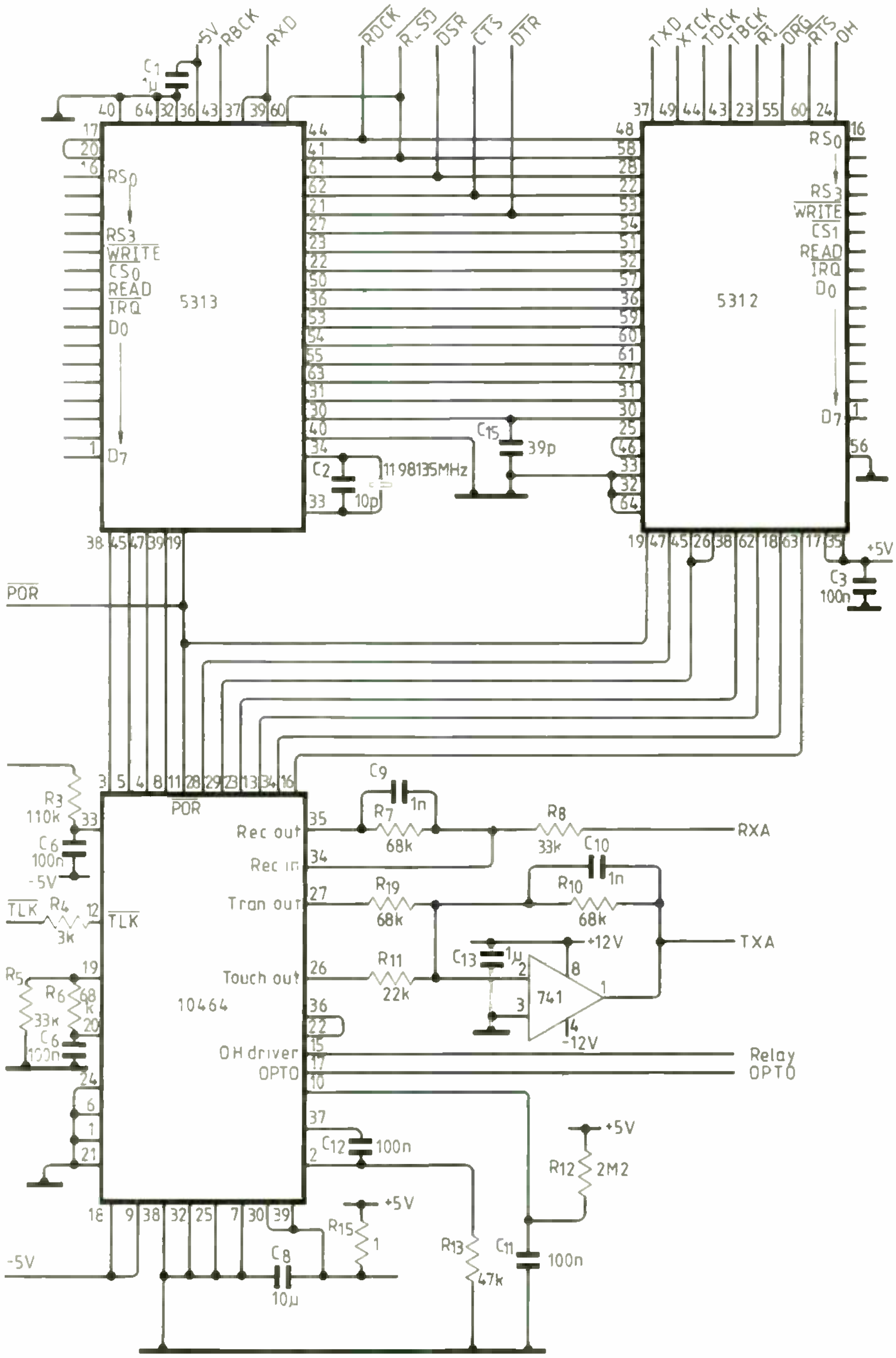


Fig.1. Circuit diagram of the V.22/V.22*bis* sub-board. This plugs into connectors on the main board (Fig.2).

fitted to prevent tinkling during pulse dialling by shunting the bell circuit. Since the modem will draw much of the available line current it was decided not to switch the telephone off, thus saving a d.p.d.t. relay. However, care must be taken not to take the phone off-hook during dialling.

Ring detection for the auto-answer function is provided by the zener-opto combination with the capacitor providing a.c. coupling.

USER ADAPTATION

Users can configure the unit to their particular needs by means of the control port, which has a multitude of possible functions. Provided on the connector are eight i/o bits as well as analogue data. Possibilities include remote telemetry systems, burglar alarms, point-of-sale data transfer, cryptographic functions, data security and a host of others. (Information about some of these is available from Anglo Computers – address at the end of this article.)

In this design, further assistance in this area has been supplied by taking the unusual step of providing the processor NMI via the RS-232 port where it may be driven either by an RS-232 input or by a pair of contacts shorting pins 24 and 25 together. It may therefore be used as an alarm input, calling a remote number when an alarm condition is present.

About 4K of the eprom is available for user software, starting at the eprom logical address 0000_{16}. The NMI routine in the main operating system will look at eprom logical address 0000_{16}. If it finds FF_{16} then it will

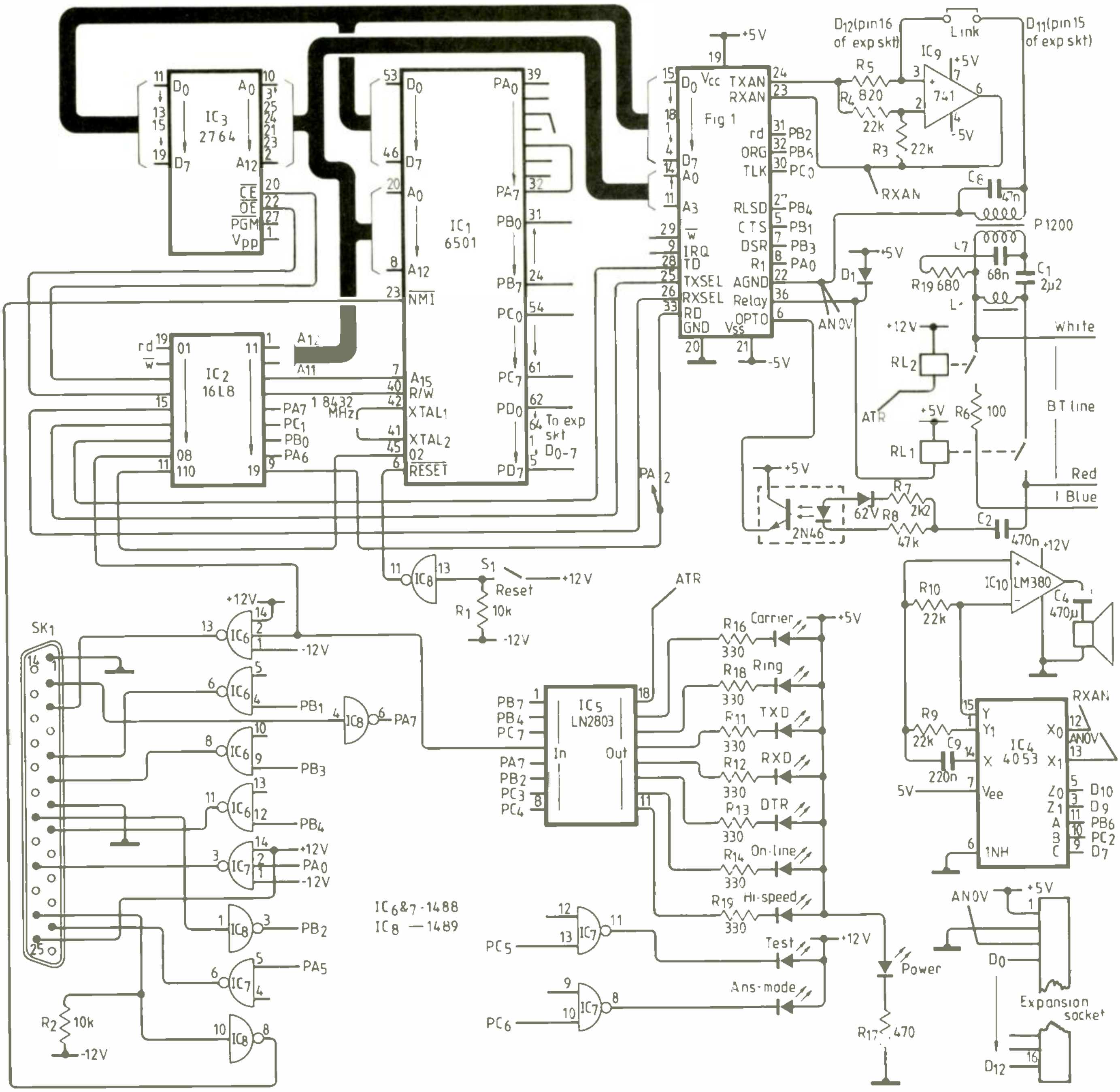


Fig.2. Main board. The modem socket (top, right of centre) can accept V.22, V.22*bis* or other modules. Software will identify which type is fitted. On the p.c.b. there is an experimental area for additional hardware, close to the expansion socket.

SOFTWARE

As the unit is primarily intended for experimental purposes, it can be operated with the user's own software (which can of course be written on a BBC microcomputer, which has similar machine-code instructions). Programmers should obtain a copy of the 6501 data sheet from Rockwell. Extra instructions in the 6501 are:

Set memory bit	SMB m, Addr
Reset memory bit	RMB m, Addr
Branch on bit set relative	BBS m, Addr, Dest
Branch on bit reset relative	BBR m, Addr, Dest

which are used as i/o control and interrogate instructions.

The system memory map is as follows:

8000-9FFF$_{16}$	Main system program
9FFA$_{16}$	NMI vector
9FFC$_{16}$	Reset vector
9FFE$_{16}$	IRQ vector
1000-100F$_{16}$	CS$_1$ (transmitter d.s.p.)
1800-180F$_{16}$	CS$_0$ (receiver d.s.p.)
0040-00FF$_{16}$	System ram
0000-0003$_{16}$	I/o ports A,B,C,D (0000 = A)

Port usage is as follows:

Bit	Port	Use
0	A	Ring Indicate from modem chips (active low)
1		Reset switch
2		Monitor (special function)
3		IRQ from modem chips
4		TXD timer input
5		High speed output
6		6501 serial out
7		6501 serial in
0	B	Receive direction (0 = normal, 1= echo)
1		Modem chip CTS
2		Modem chip DTR
3		Modem chip DSR
4		Modem chip carrier detect
5		Loudspeaker on (0 = on)
6		Modem chip ORG
7		Anti-tinkle relay
0	C	Modem chip TLK
1		Transmit direction (0 = normal, 1 = echo)
2		Speaker volume (0 = loud, 1 = soft)
3		On-line led
4		Hi-speed led
5		Test led (modem in test mode)
6		Answer mode led (modem in auto answer mode)
7		Ring led (telephone is ringing)
0-7	D	Control port (see text)

● A set of parts is available for this design from Anglo Computers. The heart of the unit, the modem engine, is available as a plug-in module in two versions – V.22 and V.22*bis*. These look identical, but software will automatically detect which one is in use. Kits are complete except for the power supply and case (a suitable case is Farnell number 148-199). Power requirements are +5V at 1.5A (regulated); –5V at 150mA (regulated); +12V at 100mA (unregulated); –12V at 100mA (unregulated).

The V.22 modem kit costs £198.38; the V.22*bis* kit costs £209.88. Both prices include inland postage (£2.50) and v.a.t. Payment (made out to Anglo Computers Ltd) must be included with your order; you should allow 28 days for delivery. No warranty is given on assembled kits.

Note that although the kit is intended to meet the requirements of the British Approvals Board for Telecommunications, it does not carry BABT approval and so may not be connected directly or indirectly to public telephone networks in the UK. Anglo Computers does, however, have BABT-inspected manufacturing facilities and can assist in obtaining BABT approval.

Table 1: Hayes command set quick reference guide.

A	Set modem to auto-answer.
Cn	Switch modem carrier on or off.
Dnn	Dial a number.
En	Switch echo on or off.
Hn	Go on or off-line (H = hook).
In	Request product code information.
Mn	Enable-disable loudspeaker.
O	Go on-line immediately.
P	Pulse dial.
Qn	Result codes sent/not sent.
R	Reverse dial mode.
Sn	Read S register.
T	Tone dial
Vn	Select verbal or result code.
Xn	Request extended result codes.
Z	Software reset.
=	Set S register.
,	Insert a one-second pause.
;	Go to command state after dialling.
A/	Repeat last command.
+ + +	Escape code.

Notes

All commands must be preceded by AT (for 'Attention').

Commands may be concatenated to form strings.

Commands with 'n' after (e.g. Dnn) require number after the command. All S registers may be adjusted but some have limits pre-set to ensure that the user stays within BABT requirements.

The escape code sequence is pause one second, send + + +, then pause one second. The modem will return to command mode without going off-line.

Table2. Functional description of modem commands. An example string might be ATT9,P618 which would tone-dial 9 (to get an outside line on a p.a.b.x.) followed by a one second pause to allow the p.b.x. to make the connection, then pulse-dial 618 (Prestel's number in London).

Command	Description
A	Causes the modem to go on-line immediately; can be used to answer an incoming call when modem is not in auto-answer mode.
Cn	Carrier on = 1, carrier off = 0.
Dnn	Dial a number in originate mode; used in conjunction with T, P, R, ; or , commands, followed by number – i.e. ATDP123 pulse-dials 123.
En	Echo on = 1, off = 0; used to echo back to the terminal what is being transmitted to the modem.
Hn	On-line = 1, normal = 0; used to go on-line immediately (i.e. close line relay) – usually in normal (modem controlled) mode.
In	0 = rom checksum sent to terminal 1 = help screens sent to terminal (for when you lose these instructions)
Mn	0 = loudspeaker off 1 = speaker on until carrier detected 2 = speaker always on 3 = toggle speaker volume
O	Go back to on-line condition after being in command mode (i.e. after escape sequence)
P	Return to pulse dial after tone dialling
Qn	Result of command codes: sent = 0, not sent = 1
R	Reverse dial – allows modem to call an originate-only modem. This command is placed after the numbers in a dial command string.
Sn	Read value of S register number n
T	Tone dial; alternative to P command
Vn	Select verbal result code: = 1 (command result sent as text string) = 0 (numeric result code)
Xn	Extended result code select: 1 = on, used by some software to provide automatic data connection; 0 = normal result code set.
Z	Resets all the above; use with care!
,	Insert 1s pause: used during dialling to provide a pause whilst changing from p.a.b.x. to p.s.t.n.
=n	Sets S register to a value n
;	Modem reverts to command state after dialling
A/	Repeat last string; used for repeat tries if target number is engaged.

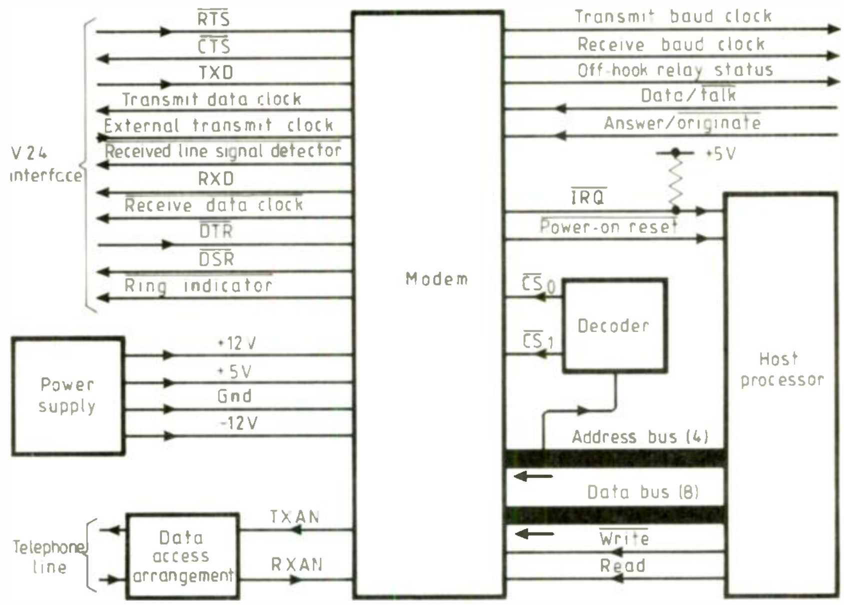


Fig.3. Functional interconnection diagram for the Rockwell R2424 chip set.

ignore the interrupt. However, if it finds something other than FF then it will treat it as an address and will execute the following code. As mentioned earlier it is as well to leave the interrupts well alone. So instead of doing a return back into the NMI routine, the user should jump instead to the Reset vector where the operating system will take over again.

Error detection and correction software has not been written for the unit as it is up to the user to decide which system suits him best. But provision has been made in the circuit for monitoring the receive input via port PA2; however the user must be confident enough to be able to write a software uart program, since the serial port is busy. Some help is given, though, in that the timing is predetermined and port PA2 is interrupt-driven.

Data rate selection, incidentally, is done by measuring the width of the start bit on the A of the AT – hence the reason for the timer connection (PA4) on the serial port. Data, parity and stop bits are determined in a similar way by studying bits 8 (and possibly 9) of the A and T. As I have mentioned before, the 6501's access to the modem is via dual-port ram configured as registers. Registers in the receive chip update at the modem signalling rate (600 baud) except ram access and ram data update which are at 7200bit/s. Registers in the transmit chip all update at 7200bit/s.

Further reading

Designer's Guide: R2424DS 2400BPS full-duplex modem device set. Rockwell International Semiconductor Products Division document number 29220N70, order number 670, January 1985.

Addresses
Anglo Computers Ltd, Cefn Llan Science Park, Aberystwyth, Dyfed SY23 3AH; tel. 0970-624321. Contact Sandra Alker.
Rockwell Semiconductors, Central House, Lampton Road, Hounslow, Middlesex TW3 1HA; tel. 01-577 1034. Contact Ken Will.

Kevin Kirk received his basic training in the Royal Air Force. Having worked worldwide for a variety of computer companies, he is now senior design engineer with Anglo Computers.

Anglo Computers Ltd is a design house specializing in the custom design of computer-based products, with a special emphasis on data communications.

BOOKS

Inside OS/2 by Gordon Letwin. Microsoft Press (Penguin Books), £18.95. Authoritative guide for the advanced programmer to Microsoft's powerful new operating system for 80286/80386 computers, written by OS/2's creator himself. Unlike some such books, which consist largely of tables of commands and system calls, this one describes each function in detail and explains the thinking behind it. Essential reading for those about to do battle with OS/2. Soft covers, 289 pages.

The Hexfet Designer's Manual, fourth edition. International Rectifier, £5 (+£2 postage). Fat data book with application notes on IR's extensive range of power mosfets. Among the application notes (which occupy 190 of the 1824 pages) are items on the do's and don'ts of using power mosfets, how to protect power mosfets from electrostatic damage, how to use surface-mounted devices; and designs for a high-frequency electronic ignition, a chopper for motor speed control, and a variety of switch-mode power supplies. This publication is available from International Rectifier at Hurst Green, Oxted, Surrey RH9 8BB (0883-713215) or from the company's distributors.

Pioneers

6. Sir John Randall (1905-1984) and Dr Harry Boot (1917-1983): inventors of the cavity magnetron.

W.A. ATHERTON

Many engineers made radio sets in their youth, but I know of only one who made an X-ray tube and X-rayed his own hand. That was Harry Boot.

To British electronics engineers the names Boot and Randall go together like silicon and chip. They invented the cavity magnetron at the University of Birmingham in 1939-40. It generated microwaves shorter and more powerful than any rival and enabled Britain's wartime radar to help defeat both U-boat and bomber attacks.

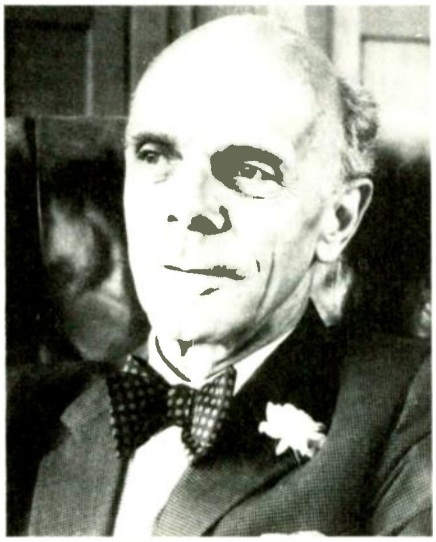
Randall and Boot not only had to invent and build the cavity magnetron but to design and build the ancillary equipment as well. Later they wryly observed that powerful microwave oscillations were eventually obtained "on the morning when all this equipment operated simultaneously"[1].

In determining just how powerful the output was they lit neon lamps some distance away and ignited cigarettes with the output lead. A succession of car headlamp filaments was burned out in trying to measure the power, which all agreed must be several hundred watts. In fact it was so great that no-one believed it could be microwaves. Days later they measured the wavelength at 9.8cm. The target had been 10cm (3GHz)! By comparison the Ventnor radar station, which they had visited and which was part of a chain in Southern England, operated at 11 metres.

Not long before, in 1937, M.L.E. (later Sir Mark) Oliphant had been appointed Poynting Professor of the physics department at Birmingham University. John Randall was the first senior researcher to join him, having established his reputation in luminescence research at GEC in Wembley, London. Harry Boot, meanwhile, was an undergraduate in the same department. Boot graduated with honours in 1938 and stayed to do a Ph.D.

With war approaching, Oliphant considered what role his department could play. Radar would need high-power generators of microwave radiation. On a visit to Stanford University in America in the first half of 1939 he learned all he could about the Varian brothers' newly invented klystron, a possible source of such microwaves, and about W.W. Hansen's ideas for cavity resonators.

By September he had a contract from the Admiralty to develop microwave generators and detectors. Before war was declared his staff had studied existing radar stations, especially that at Ventnor on the Isle of Wight. It was, of course, secret and they were asked "would we please not tell anyone about it"[1].


J.T. Randall (University of Edinburgh).


H.A.H. Boot (University of Birmingham).

On their return to Birmingham, work began on klystrons which were thought to offer the best chances of producing microwaves with the desired 10cm wavelength. Such a wavelength would permit aircraft to carry small dish aerials giving narrow beams which would not suffer from gross reflections from the ground. Randall and Boot, meanwhile, were asked to study the Barkhausen-Kurz tube as a possible microwave detector.

CAVITY RESONATORS

By now the physics department was buzzing with talk of klystrons and cavity resonators. Meanwhile Randall and Boot worked on the Barkhausen-Kurz tube but, "We were unsuccessful and disenchanted with this task". They were, of course, naturally interested in the main problem: the generation of microwaves. And they could see that the klystron group had problems.

The only other known sources of microwaves were sparks (as used in early radio) and the split-anode magnetrons which dated from the 1920s. The latter had been studied at GEC in Wembley, and in France, Germany, America, Russia and Japan. But below 10cm, the target wavelength, existing magnetrons had vanishingly small powers.

But another microwave resonator was known to Randall. In July 1939 he had spent a short holiday in Aberystwyth where he had bought an English translation of Heinrich Hertz's book "Electric Waves". Back in 1889 Hertz had used a resonator as a detector in his experiments; it was simply a wire bent into a circle with a small gap as the detector.

This resonator was a loop and not a cavity, but it became the springboard to the cavity magnetron because Randall thought of extending the loop into a cylinder and the gap into a slot (Fig.1). A number of these slotted cylinders would fit around the cathode of a conventional magnetron. Dimensions were estimated using an equation published in 1902 which stated that Hertz's loop produced a wavelength 7.94 times its diameter.

It was now November 1939 and war had begun.

The device was simple to make from a block of copper; and the first, completed in December 1939, was truly a lab prototype. It was continuously pumped to maintain the vacuum needed and was sealed with sealing wax. Two water-cooled plates supported the cathode which, if it burned out, could be renewed through holes which were sealed with halfpennies held on with wax.

A home-made 16kV power supply, the high-voltage rectifiers, the diffusion pumps and the cavity magnetron "operated simultaneously" on 21 February, 1940. The results were spectacular.

The contribution of Randall's former colleagues at GEC, E.C.S. Megaw and S.M. Duke, was vital in turning the laboratory prototype into a rugged industrial product. Peak powers of over 10kW at 10cm were soon obtained. By May 1940 an experimental radar set using a pulsed 10cm cavity magnetron had been built.

One defect of the device, a tendency to jump to a different frequency when pushed hard, was overcome by "strapping", a method invented by James Sayers of Birmingham University in August 1941 by which alternate anodes were shorted together. By the end of the war hundreds of thousands of cavity magnetrons had been produced on both sides of the Atlantic.

JOHN RANDALL

John Randall was a rarity in modern science: a good administrator and researcher. His outstanding career spanned three quite different areas: solid-state physics, wartime radar, and biophysics. Surprisingly, to engineers, it was the latter which has been judged as the most significant. He "built up a biophysics laboratory that was a world leader..."[2].

Born at Newton-le-Willows in Lancashire on 23 March, 1905, John Turton Randall was the son of a nurseryman, from whom he learned to love gardening. He often wore a flower in his button-hole and even in retirement at Edinburgh he turned rough ground into an impressive garden. He was never one to do things by halves, having a reputation for ambition, perseverance and getting things done. He was knighted in 1962.

After attending the local Ashton-in-Makerfield grammar school (for which his father had scraped together the fees) Randall entered the University of Manchester. His first-class honours degree was followed by an M.Sc. in the physics department headed by W.L. Bragg, famous for his work on X-ray analysis. Bragg advised Randall to take a career in industrial research. "I imagine they did not think well enough of me to keep me on," said Randall[2].

So it was that in 1926 Randall joined the staff of GEC at Wembley as a rather inexperienced, and socially rough, research physicist. Seven years later he was, in his own words, "no longer unhappy or insecure". Perhaps the fact that he was also now a married man helped. His work included research into phosphors for discharge and fluorescent lamps.

By 1937 he was ready to move back to a university environment. Finding somewhere with a vacant position and the right money was a problem but it was solved with the aid of a Royal Society Warren Research Fellowship of £700 per annum. For this Randall acknowledged the help of Bragg and R.H. Fowler, who was a scientific adviser to GEC.

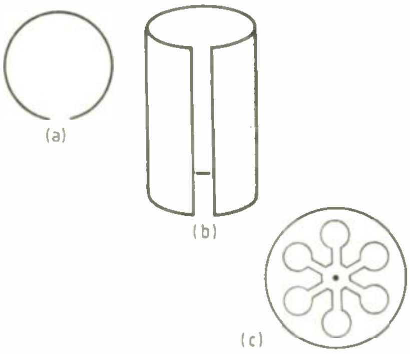
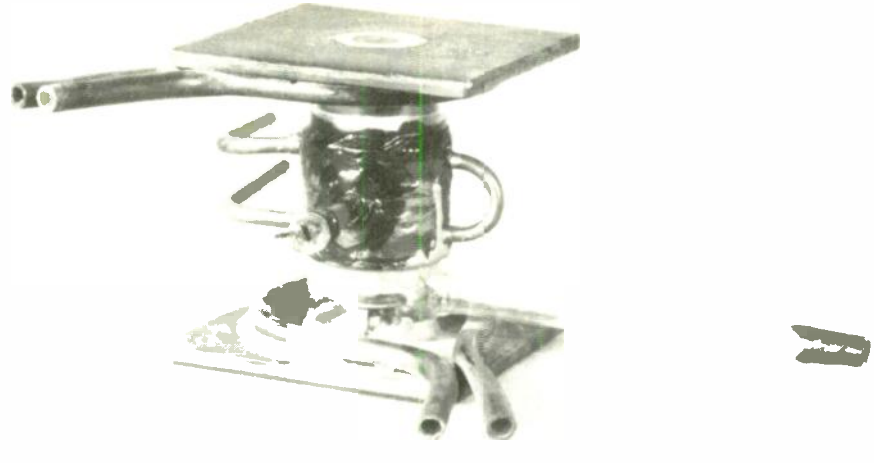


Fig.1. Evolution of the cavity resonator (after Lazarus[4]). Left to right: Hertz's loop with spark gap (1887); Randall's extension to a cylindrical resonator (1939); six resonators arranged in a block around a cathode.



The first cavity magnetron (Science Museum picture, Crown copyright).

With this fellowship Randall went to the University of Birmingham. After the cavity magnetron work, in the summer of 1943, he moved on to Cambridge University and soon after to St Andrews as Professor of Natural Philosophy. There his love for plants perhaps helped steer him towards biophysics. In 1946 he became a Fellow of the Royal Society and was appointed to the Wheatstone Chair of Physics at King's College, London, where he stayed until he retired in 1970. There his biophysics research really came to the fore and a whole new story began. His staff made outstanding contributions to research on cell division, DNA, muscle contraction, collagen and other areas.

A researcher to the end, he 'retired' at 65, not to a country cottage, but to a lab in the zoology department at Edinburgh University. There he built a whole new research team!

HARRY BOOT

When Randall arrived at Birmingham in 1937, Oliphant was strengthening the nuclear physics side of the department. As part of that task Professor P.B. Moon was assembling a 300kV charged-particle accelerator with the able assistance of a 20-year-old research student who had acquired a reputation for getting difficult apparatus to work. His name was Henry Albert Howard Boot, usually known as Harry Boot, and he loved making things big: the biggest voltage, biggest power, highest vacuum, or whatever.

Boot was born on 29 July, 1917. He attended King Edward's High School in Birmingham before becoming an undergraduate at Birmingham University, having meanwhile performed that home-made X-ray of his hand. After gaining his honours degree in 1938 he studied for a war-scarred Ph.D., the magnetron work being classified as secret.

In 1943 the Physics Department returned to the study of atomic physics and Boot moved for a time to British Thomson-Houston at Rugby (since part of AEI and now GEC) to continue the development of magnetrons. He rejoined the department for three years after the war and contributed to the Birmingham cyclotron.

But in 1948, about the same time that he married, he heard of a vacancy for a principal scientific officer with the Royal Navy Scientific Service at Baldock in Hertfordshire. He spent the rest of his career there[3]. His work on microwaves and magnetrons continued and led him into research on plasma physics and lasers. Quite early on, he built a 10cm 10MW magnetron and always maintained that the magnetron had one undying advantage over the rival klystron: it was "incredibly cheap".

For some 30 years he and his wife Penny lived in a thatched cottage at Rushton near Cambridge. There they raised their family of two boys. With his five acres of land it is perhaps surprising to learn that he disliked gardening, despite his close association with Randall, the keen gardener. Fortunately his wife enjoys gardening and whilst she and John Randall discussed the roses Harry Boot was content to think of his own great love, sailing. The waters off the East coast of England were his favourite haunt.

Along with John Randall he received a number of awards for the magnetron work, including one of £50 from the Royal Society of Arts for improving the safety of life at sea. However, after the war, with Sayers, they shared £36 000 from the Royal Commission on Awards for Inventions.

Harry Boot died on 8 February, 1983, aged 65. He is sadly missed by his widow, who now lives in Devon overlooking a river mouth where Harry Boot would have loved to sail. One of the melancholy tasks she had to perform was clearing the garage of a collection of some 50 assorted magnetrons, both old and new. A good home was found for them at a London polytechnic. Even now she still has "two or three in the loft at home".

1. H.A.H. Boot & J.T. Randall, "Historical notes on the cavity magnetron," *IEEE Trans.* ED-23, pp.724-729, July 1976.
2. M.H.F. Wilkins, "John Turton Randall", Biographical Memoirs of the Royal Society, 1988.
3. A.L. Norberg, transcript of an interview with H.A.H. Boot, Bancroft Library, University of California, Berkeley, 1979.
4. M.J. Lazarus, "Electromagnetic radiation: megahertz to gigahertz", *Proc. IEE*, vol.133, Pt A, pp.109-118, March 1986.

The author wishes to thank the University of Birmingham, Prof. M.H.F. Wilkins, and Mrs P. Boot, for information given in the preparation of this article.

Next in this series of pioneers of electrical communication: the Siemens brothers, founders of an electrical empire.

SATELLITE SYSTEMS

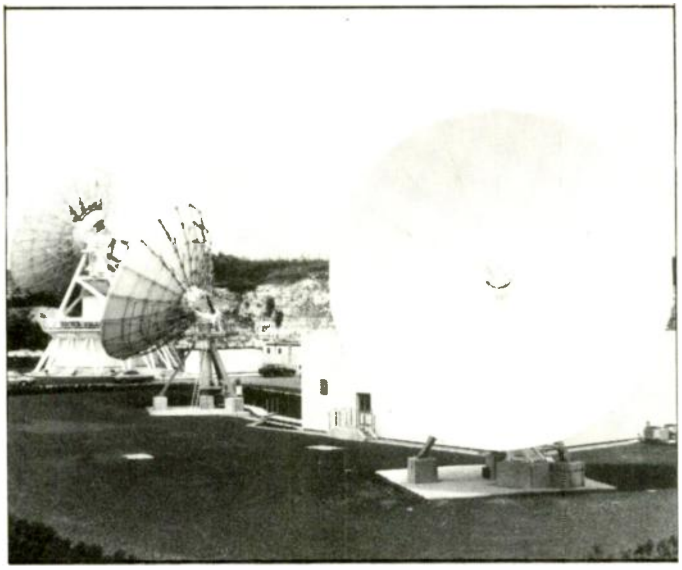
Enough space left?

Is the geostationary satellite orbit in danger of being used up? Ever since it began to be occupied in the early 1960s, following Arthur C. Clarke's famous October 1945 proposal in *Wireless World*, this looming possibility has been under discussion. For the g.s.o. is a unique, limited, natural resource – though not expendable like North Sea oil. A CCIR working party has been considering the engineering and commercial implications of this fact of nature for well over a decade.

Recently an IEE discussion meeting took a fresh look at the matter. It was led by specialist engineers from telecommunications and broadcasting – the main future users of the g.s.o. – and included questions and comments from the audience. To put you out of your misery, if you are that much concerned, the experts' opinion was reassuring. They agreed there is plenty of space left in this orbit at the moment, and there will be for some time, as long as we take care to use it efficiently by good planning and systems engineering. Nobody ventured to qualify this conclusion by suggesting a time limit when we might expect to see the 'full house' sign going up.

The IEE meeting was probably arranged for early 1988 because in August this year the ITU will be holding in Geneva the second part of a World Administrative Radio Conference on "the use of the geostationary satellite orbit and the planning of space services utilizing it." The first half of this WARC took place in 1985 and a report on it by David Withers appeared in the December 1985 issue. Important decisions will be made for the future, particularly on rules to guarantee equitable access to the orbit by all countries in the world.

A non-specialist person considering this question of limited space in the g.s.o. for the first time might be forgiven for thinking it had to do with physical space in the literal sense. An analogy would be a circle of wire, geometrically defined by the laws of celestial mechanics (the orbit), on which beads (the satellites) were being threaded. You could keep on adding beads until they were tightly jammed shoulder to shoulder, and that would be the limit. The IEE meeting, however, made it clear that this was not the most important problem.



The UK is making even more use of the geostationary orbit now that BTI's competitor, Mercury Communications, is continuing to expand its satcom services. Shown here is part of Mercury's Earth station site at Whitehill, Oxfordshire. The 13 metre Marconi antenna in the foreground, conforming to Intelsat Standard B, is an example of the smaller Earth-terminal dishes increasingly being used for public telecommunications. It provides high speed data and combined voice and data to the Far East and Australia. When a further two Standard A antennas are installed (November 1987 issue, p. 1154) the company will have six satcom systems operating from this site. Picture by Marconi.

A geostationary slot like 19°W, although theoretically a unique point on the orbit, is in fact a nominal station with positional tolerance of $\pm 0.1°$. A satellite in this slot is allowed to drift about within a square of 65km sides. Within that area there is, of course, room for more than one spacecraft. When telecomms traffic is being transferred from an old satellite to a new one, for example, it is normal practice for the new comsat to be brought by telecommand very close to the old one within the slot.

A speaker mentioned that in fact anything up to 12 satellites could be located at one nominal position. Since the individual orbits in such a group differ from each other very slightly, the spacecraft do not remain at fixed distances apart but drift about relative to each other. Theoretically they could collide, but the 'mean time between collisions', according to this speaker, was to be measured in hundreds of years.

The limitations imposed by the g.s.o. that satcoms engineers seem mainly concerned about are in orbit/spectrum planning, the communications capacity of existing satellites and interference between different satellite networks using the orbit. As examples of planning problems, A.L. Witham (IBA) and P.A. Ratliff (BBC) outlined and compared the two d.b.s. plans resulting from WARC 77, for ITU Regions 1 and 3, and RARC 83 for Region 2.

Although the criteria and methods adopted at these two conferences were different (see February 1986 issue, pp. 74-76), both schemes were examples of *a priori* planning. There was little or no previous experience to draw on and decisions had to be made as acts of faith. The requirement that every country had to receive an orbital slot (or slots) and an allotment of frequencies meant that orbit/spectrum spaces had to be reserved for many developing countries which would either take a very long time to occupy them or be unable to use them at all. Thus fair shares in the long run must produce inefficient utilization for the time being.

Something very similar is taking place in the telecommunications satellite field. Paul Thompson (BTI) called it the problem of "paper satellites." The telecomms organizations of many countries were routinely going through the first two stages of satcom network planning required by the international regulations – publication of intention and co-ordination with other users. But the third and final stage, of notification that a network was actually being built, often failed to materialize. He showed statistical graphs of the numbers over a period of years. While the 'intention' and 'co-ordination' stages of reporting rose steadily, the number of 'notifications' fell to practically zero in 1985/86. An expected boom in satellite launches in 1987 did not in fact occur.

In reply to a question, Dr Thompson said he thought this phenomenon was really the result of defensive activity by many developing countries. They had a fear of being left out and that the whole planning process was being manipulated by the "big boys" – the economically advanced countries – who had already learned all the tricks of the trade and were using this advantage to take more than a fair share of the orbit/spectrum resource. Other claimants adopting the 'paper satellite' ploy had financial gain in mind. Dr Ratliff said it was perhaps necessary to give some form of guarantee to those countries who felt they were being left out.

In general Dr Thompson considered that the telecomms planners and engineers were about to take a more flexible approach than was possible with the *a priori* method. He suggested, half-joking, half-serious, that the official abbreviation FSS (Fixed Service – Satellite) should now stand for Flexible Satellite Service. More efficient utilization of the limited orbit could be obtained by greater flexibility in both planning and satcom network engineering. The g.s.o. was not expendable but was certainly "exploitable" within the guidelines of the radio regulations.

On the engineering design of spacecraft and Earth stations, he listed a variety of ways in which this legitimate exploitation was already going ahead. Satellites of increased mass and power (see January 1988 issue, pp. 23-27) provided more communications capacity per spacecraft and therefore reduced the number of satellites required in the orbit.

Spot beams, specially-shaped beams and dual polarizations allowed considerable re-use of the available frequency spectrum. Antennas were being designed to minimize the amount of sidelobe radiation, thus reducing interference between networks and allowing closer spacing of satellites in the orbit.

Modulation schemes tolerant to interference were coming in, while improved filtering methods were reducing adjacent channel interference. Techniques for interference cancellation were being developed, though a good deal of r&d was still needed in this area.

At Earth stations, greater flexibility was being obtained by the trend towards smaller antennas. Being small, they could be moved about more easily to suit changing requirements and could also be shielded from interference by making use of the local terrain. Because they were also cheaper than earlier designs, their owners could afford to take risks in purchasing and deploying them. The offset Gregorian reflector system had been particularly advantageous for British Telecom.

A survey of the g.s.o. as a whole revealed that spare transponders were often available in comsats. This, said Dr Thompson, suggested that greater orbital efficiency could be gained by having multi-administration satellites. In other words, a given comsat would be used not just by a single owner/operator but in an integrated, co-operative fashion by, for example, the Intelsat, Eutelsat and Intersputnik organizations.

Another possible answer to the natural limits of the g.s.o. is to move into other kinds of orbits. The highly elliptical ones used by the USSR since 1986 are, of course, well known, and now West European researchers are starting to consider them (November 1987 issue, p. 1158). But these 'Molniya' orbits are at high angles of inclination (e.g. 63°), are not geostationary and are mainly restricted to those regions that are centred below the apogee.

At the IEE discussion, brief mentions were made of orbits which are geosynchronous but inclined at an angle of a few degrees to the equatorial plane and therefore do not allow the satellites to be truly geostationary. Such 'inclined' orbits, as they are rather vaguely described, are in fact already being designed for parking spare, non-operating satellites which are due to be shifted into the proper geostationary position for service at some later time. But, as a speaker pointed out, the limitations here are set by the very proximity to the g.s.o.: mutual interference would be a serious problem.

A German system which has been presented to the ESA uses three satellites in different elliptical paths. Instead of a geostationary point in space, there is a small, narrow geostationary loop, which is always occupied by a spacecraft. A further possibility mentioned at the meeting is a non-geostationary system which uses two satellites with 12-hour periods.

Meanwhile, as another contributor pointed out, one can't really say that the g.s.o. is running out of space at least on a frequency basis while there is still a good deal of spectrum available in the 20-30GHz satellite bands. This region, however, will be very expensive to implement because of the high design and manufacturing costs of millimetre-wave equipment.

Astra launch date

The medium-power television satellite Astra is due to be launched on 1 November this year, according to latest information from Arianespace (see June and September 1987 Satellite Systems for details). At the time of writing, SES, the Luxembourg operation company, has not yet signed up any tv programme producing firms to occupy the 16 channels available. Meanwhile, considerable competition is developing between SES and BSB, the operating company for Britain's d.b.s., for the attention of the potential UK audience.

Geostationary satnav study

Inmarsat could have a satellite navigation system in operation by 1990, according to George Kinal, the international co-operative's group leader for satnav services. As reported in January 1988, this would use techniques similar to those of GPS and Glonass but with geostationary satellites. Inmarsat has just awarded a study contract to STC Technology Ltd to see what can be achieved on the existing comsat system.

The study will be in two parts. First, STC will define optional methods for providing radiodetermination and navigation services. These methods could be passive, in which the mobile determines its position by measurements made on satellite signals received, or active, where the user receives such signals but also transmits a signal for measurement and position determination to be performed at a central point. Hybrid modes are also possible. In these the mobile performs all the measurements but the computations for positioning are done at the central point.

Inmarsat will then select the methods which seem most promising and STC will develop them further to produce a final report on system requirements.

Satellite Systems is written by Tom Ivall.

Radio engineering terms in satellite links

Attenuation

In transmission from the satellite to ground the signal power undergoes losses, also expressed in dB. A fundamental one is the *free space loss*, LdB. This is what occurs in the theoretical condition of both the transmitting antenna and the receiving antenna being isotropic. The power from the transmitting antenna radiates uniformly in all directions, and at the receiving antenna can be considered as evenly illuminating the interior of an imaginary sphere with an inside surface area of $4\pi r^2$, where r is the distance between the antennas. The amount of power falling on unit area of the sphere is important to know for reception purposes. This is the power density, expressed in dBW/m^2, which is usually called the *power flux density*. The free space loss is due partly to the fact that power flux density (p.f.d.) is inversely proportional to r; this is called the *spreading loss* and is equal to $10\log_{10}4\pi r^2$ dB. Another contribution, dependent on frequency, is due to the isotropic aperture value for the receiving antenna. This factor is given by $10\log_{10}4\pi/\lambda^2$dB.

Overall, the free space loss is given by the formula $L(dB)=20\log_{10}4\pi r/\lambda$. For example, if the satellite is geostationary, making r = 35 800km (approximately) and if the carrier frequency is 12GHz, making λ = 25mm, then L comes to 205.1dB. In practice, of course, this free space loss is partly counteracted by the radiation patterns of the transmitting and receiving antennas, so that the radiated power is not, in fact, isotropic.

Another unavoidable form of attenuation is due to the signal's passage through the Earth's atmosphere: AdB. Losses in the gases are negligible, but those due to water in the form of clouds, rain, mist, sleet and snow are more severe. These losses increase at low elevations. Moderate rain causes a loss of about 1–2dB at 12GHz, heavy rain anything up to 10dB and torrential rainstorms anything up to 20dB. The levels of rainfall experienced in Europe are such that an attenuation of 2dB would be exceeded for not more than 1% of the least favourable month (or 0.25% of the time overall).

Power budget

At the earth station the signal is picked up by the receiver dish antenna, which has a gain of G_R (given by the formula for G above), and this results in a power P_R at the feed point of the antenna. Thus the overall power budget calculated from the gains and losses mentioned above is:

$$P_R = P_T+G_T-L-A+G_R \text{ dB}$$
$$= \text{e.i.r.p.}-L-A+G_R \text{ dB}$$

As an example, assuming the above-mentioned geostationary satellite giving an e.i.r.p. of 60dBW, an *atmospheric attenuation* of 1.5dB and a typical receiving antenna gain of 42dB:

$$P_R = 60-205.1-1.5+42 \text{ dBW}$$
$$= -104.6\text{dBW (or approx. 40pW)}$$

To be continued

Image movement in stereophonic sound systems

The effects of off-centre listening, including elevation of the image

F. O. EDEKO

The principle of stereophonic sound reproduction dictates that the listener occupies a central position. However, it is not always the case that one is able to occupy this central position: indeed, under home listening conditions, it is rarely possible.

If a listener's head occupies any position along the horizontal axis other than the central one as shown in position 2 of Fig.1, then this is, technically speaking, an off-centre listening position. Under this condition, the rules governing the localization of stereophonic images become inapplicable. Depending on the direction and amount of shift off-centre, the listener could perceive an image located within the stage width or at the position of either of the two loudspeakers.

For low frequencies, where the reconstructed wavefront exhibits virtually constant amplitude and phase over a large region in space, small off-centre movements do not cause significant image displacements from stage centre for the case of equally driven loudspeakers. But, as frequency increases, the reconstructed wave pattern becomes more complex and small off-centre displacements by the listener will result in large image displacements.[1,2].

The wavefront reconstruction theory proposes that the information available to the ear/brain combination for image localization is deduced as a result of interrogation by the head width of a section of the reconstructed wavefront. Therefore, an off-centre listening position implies that the head becomes immersed in a different section of the wavefront.

The wavefront $H_2(x)$, reconstructed by two loudspeakers along the X-axis, was developed in reference 1 and is expressed as

$$H_2(x) = \exp[jk(R+x^2/2R)]\,[L\exp[jk \times \sin\theta_0] + R\exp[-jk\sin\theta_0]] \quad (1)$$

The head interrogates a section of this wavefront depending on the position of the listener along the X-axis. The movement of the listener's head to position 2, in Fig.1 essentially does not change the wavefront $H_2(x)$. What happens is that the head is now in contact with a different portion of this wavefront, the parameters of which could be very different from that in the central position.

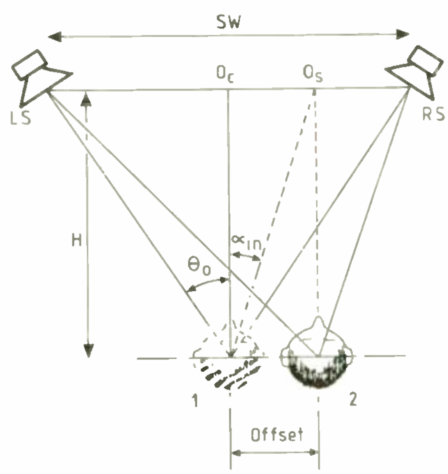


Fig. 1. Off-centre listening. In the experiments, stage width (SW) is 230cm and H is 200cm. With the head central, speakers and head form an equilateral triangle.

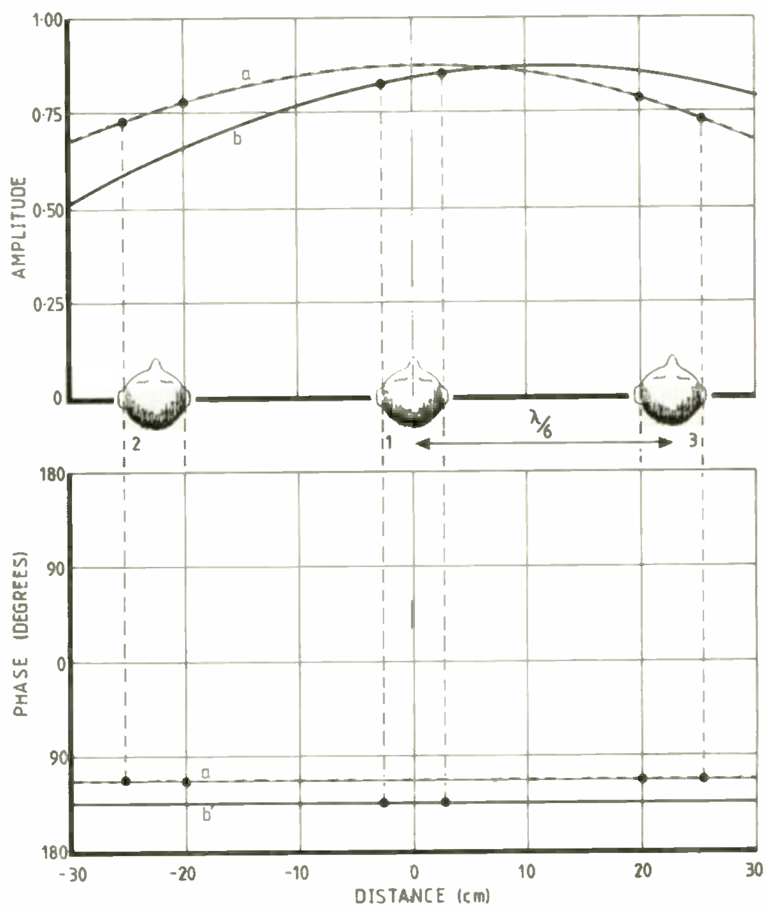
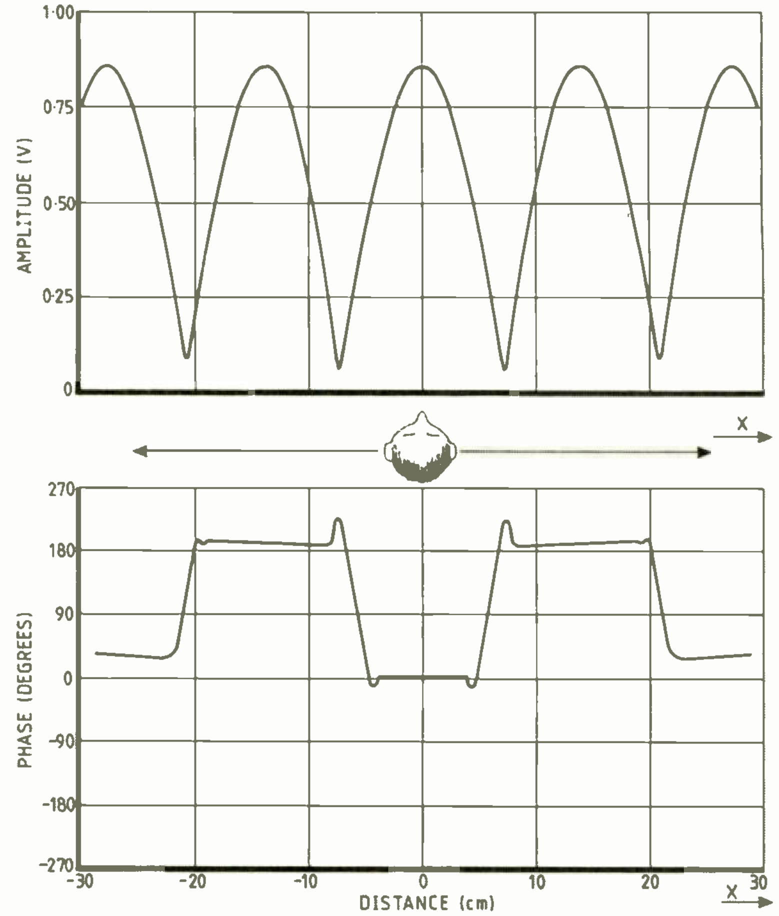


Fig. 2. Wavefront reconstruction. Parameters an and a' are amplitued and phase respectively over a region of 60cm for a 250Hz signal. Left speaker lages right speaker by 60 degrees. At b and b' are amplitude and phase exhibited when left speaker leads right speaker by 60 degrees.

Fig. 3. Amplitude and phase of the wavefront for a signal of 2500Hz – two in-phase speakers equally driven.



PHASE DELAY

For the case of equally-driven loudspeakers, it has been demonstrated in reference 2 that an interchannel phase difference causes the reconstructed wavefront $H_2(x)$ to be displaced along the X-axis towards the leading loudspeaker, relative to the wavefront for in-phase, equal-amplitude loudspeakers.

Consider now the case where phase delay is zero but the subject's head is moved to a new position, where the head comes into contact with different section of $H_2(x)$. If this section of the wavefront corresponds to that which the head would interrogate for an on-centre listener if a given phase delay had been introduced, then the subjective perception of the image will be essentially the same. This implies that off-centre listening is a form of phase delay.

The shift in wavefront due to an interchannel phase difference of $\gamma°$ can be determined by examining equation (1). For the ease of equally driven loudspeakers, and supposing the right speaker leads the left by $\gamma°$, then the reconstructed wavefront as shown in reference (2) is given as

$$H_2(x) = 2L \exp(j\frac{\gamma}{2}) [\cos(kx \sin\theta_0 - \gamma/2] \quad (2)$$

Equation (2) will be maximum if

$$kx \sin\theta_0 - \frac{\gamma}{2} = 0 \quad (3)$$

Hence the maximum will occur in a shifted position along the X-axis given as

$$x = \frac{\gamma}{2} \cdot \frac{\lambda}{2\pi \sin\theta_0} \quad (4)$$

For $\theta_0 = 30°$, the shift x is

$$x = \frac{\gamma}{2} \cdot \frac{\lambda}{\pi} \quad (5)$$

A 180° phase delay between the speaker signals results in a wavefront displacement of $\lambda/2$.

For example, suppose $\gamma = \pi/2$: using equation (5), the wavefront displacement will be $\lambda/4$. If a listener moves off-centre by an amount equal to $\lambda/4$, then a $-\pi/2$ interchannel phase difference is equivalent to an off-centre movement of $\lambda/4$ for that given frequency. In this respect, off-centre listening can be considered as a form of phase delay. This was correctly noted by Leakey[3].

However, very important differences exist between phase delay and off-centre listening. Phase delay is usually considered in cases of equally-driven loudspeakers but off-centre listening encompasses also the case of $R \neq L$.

More importantly, for phase delay to be equivalent to off-centre listening, it is necessary that the listener moves off-centre by the specified amount toward the speaker that

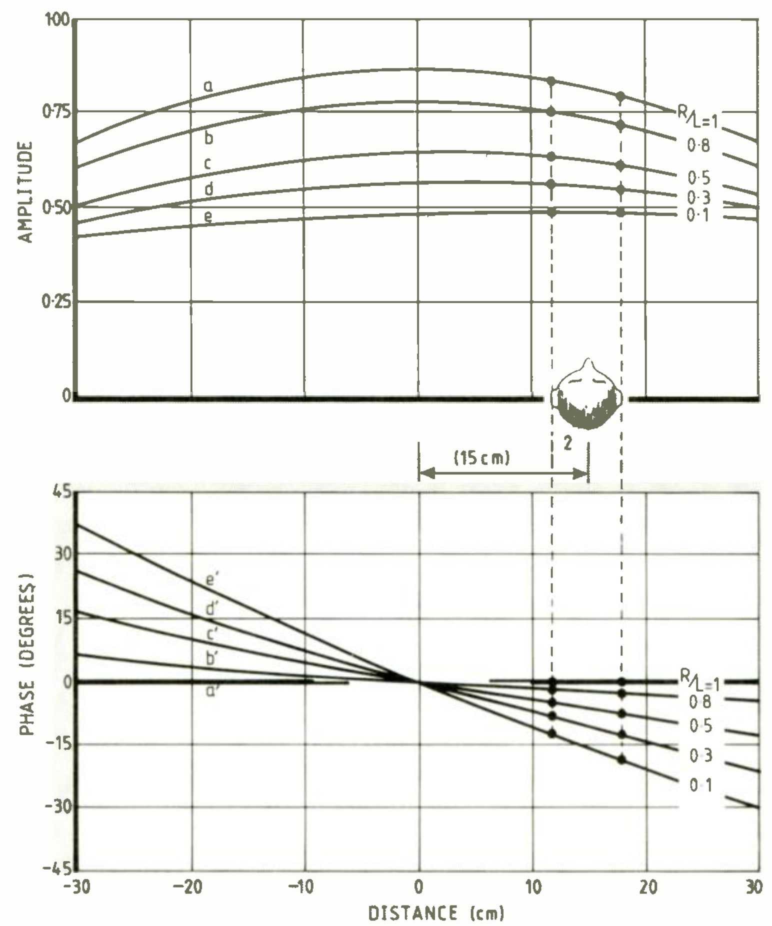


Fig. 4. Wavefronts in contact with the head when shifted to right by 15cm, for various L/R ratios, at 250Hz. Left-ear signal is larger than right-ear signal – reverse of expected effect.

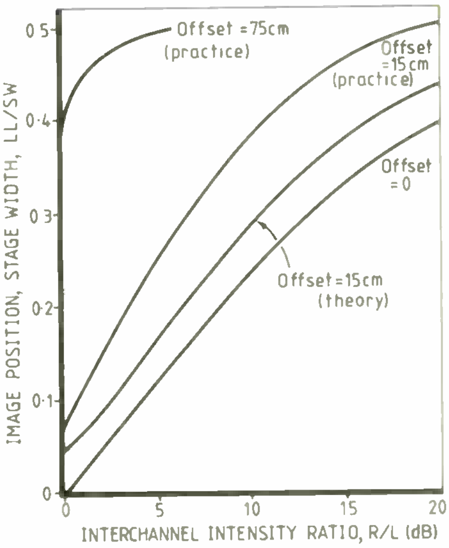


Fig. 5. Image localization is offset listening positions for a varying intensity ration between speakers. Signal was third-octave pink noise at 250Hz.

lags in the case of phase delay for R = L. Figure 2(a) shows the wavefront $H_2(x)$ reconstructed by two in-phase, equally driven loudspeakers over a region of $-X \leq x \leq X$ where x = 30cm for a 250Hz signal, and Fig. 2(b) when the left lags the right loudspeaker by 60 degrees. This 60° phase difference corresponds to an off-centre movement of $\lambda/6$ = 22.9cm. If the movement is towards the right loudspeaker, as shown for head position 3, as phase delay would suggest, then the section of the wavefront (a, a′) in contact with the head has different parameters from that in centre position 1 for a 60° delayed wavefront. However, a shift to position 2, towards the lagging, would result in identical wavefront parameter (a, a′) across the head, as compared to position 2 (b, b′). For aesthetic reasons the head is not drawn to scale.

The localization of images in off-centre listening positions therefore cannot be only on the basis of the theory developed for phase delay. A more comprehensive approach that takes into account the directional information in the phase of the wavefront when R ≠ L is required.

For large off-centre displacements, the image is likely to be perceived as coming from the speaker nearer to the subject. This is because the head could, under this condition, be in contact with more than one interference lobe, a situation that implies a discontinuity in the phase of the wavefront. This practically inhibits the perception of a single, well-defined image. Because of the increased complexity of the interference pattern as frequency increases, even small displacements off-centre by the head will result in discontinuity in the phase characteristics of the reconstructed wavefront. It has been observed in practice that if a listener moves slowly off-centre along the X-axis (Fig.1), the interference pattern of the field $H_2(x)$ can be perceived. At certain positions, a loud image is perceived, then the loudness level decreases to a minimum and then starts to increase again to a maximum level, the effect repeating with further movements along the X-axis. This subjective perception is most noticeable for high-frequency signals. Figure 3 represents the reconstructed wavefront $H_2(x)$ for a 2500Hz signal when the two in-phase loudspeakers are equally driven.

For such a complex wavefront, very small head displacements from the median plane will result in discontinuity in the phase of the reconstructed field and the perceptions of more than one image or diffused images are very likely possibilities, as suggested earlier by image migration theory[1].

With this in mind, it is logical to confine the use of wavefront reconstruction in developing an image localization theory for off-centre listening positions to conditions in which the amount of displacement from the centre does not result in the head being immersed in more than one interference lobe: this is applicable mainly to low-frequency signals. The two-loudspeaker stereophonic system cannot provide enough usable region in space for high-frequency signals to satisfy off-centre listening conditions.

IMAGE LOCALIZATION AT LOW FREQUENCIES

The nature of the wavefront in contact with the head in a given off-centre position provides an indication of the subjective evaluation of the stereophonic image. Wavefronts reconstructed by two loudspeakers over a 60cm range for a 250Hz tone are shown in Fig.4 for R = L. The position of the head (not to scale) of a listener in a 15cm off-centre position to the right relative to the wavefront is also shown.

The phase of the section of the wavefront is essentially constant, which implies an image directly in front at position 0_s in Fig.1. The amplitude, however, is not constant: the left-ear signal is larger than that of the right. This would indicate that the image is located to the left of the head. The contribution of amplitude to image localization in this case tends to work against the direction of shift of the listener. This can be considered as an effect which pulls the image away from point 0_s towards the stage centre, an effect which is likely to cause image spreading over a frequency range. The image will therefore be perceived to lie between points 0_s and 0_c of the stage width. The amount of displacement of image from position 0_s due to the ear signal difference is due to an image position α_a, which can be calculated using the stereophonic sine law[1,3] as

$$\alpha_a = \arcsin\,[(R-L)/(R+L)]\,\sin\theta_0 \qquad (6)$$

where R and L are the average instantaneous pressures at both ears from left and right speaker. In wavefront reconstruction, the question of crosstalk does not arise: therefore, the values of L and R can be taken as sound pressure at positions $-X_m$ and X_m of the reconstructed wavefront $H_2(x)$. If the amplitude values of the wavefront at $-X_m$ and X_m are p and q respectively, then equation (6) can be re-written as

$$\sin\alpha_a = [(p-q)/(p+q)]\,\sin\theta_0 \qquad (7)$$

where θ_0 in the azimuth angle of speakers (Fig.1)

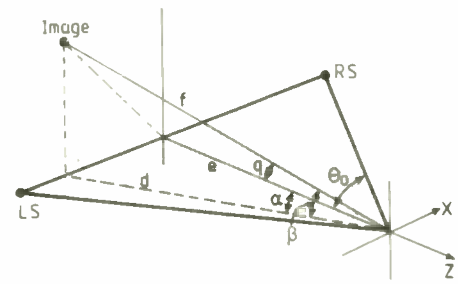


Fig. 6. Elevation of the image.

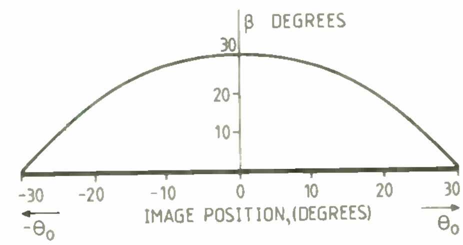


Fig. 7. Curve of image elevation across the stage width with varying interchanel intensities.

The position of the image as determined by the constant phase is $\alpha_{ph} = 0^0$ with respect to point 0_s. However, the off-centre movement creates an initial image displacement relative to the stage centre. This initial displacement α_m is given as

α_m = arc tan [shift off-centre/listening distance] (8)

For a shift of 15cm and listening distance of 200cm (Fig.1), initial displacement α_m = 4.28°. Therefore, the actual image azimuth angle relative to stage centre is:

$$\alpha = \alpha_{ph} + \alpha_m - \alpha_a \qquad (9)$$

For cases when R ≠ L (Fig.4, b,b′ – e, e′) the image azimuth angle α_{ph} relative to point 0_s of the stage width can be deduced by the best-fit phase approach developed in references 1,2. The pressure levels at the two ears for each ratio of R/L are used in equation (7) to find α_a, and the actual image position can then be determined by equation (9).

Such a scheme has been implemented in software using the stereophonic system geometry in Fig.1 for an off-centre movement of 15cm to the right and a 14cm head width. The simulations were implemented for 250Hz signal. No assumptions were made in generating $H_2(x)$. Results of computer simulations of actual image positions for the given off-centre listening position are shown in Table 1 and in the graphs of image displacement in terms of stage width with interchannel intensity ratio in Fig.5.

It is evident from these graphs that off-centre movements do result in larger image

Frequency (Hz)	Inter-channel intensity ratio, R/L	Image position azimuth angle (degrees)	Image position/ stage width LL/SW
250	1.0	3.14	0.052
	0.8	5.46	0.083
	0.5	12.57	0.194
	0.3	18.8	0.296
	0.1	26.63	0.436

Table 1. Simulation: image localization in a 15cm off-centre position. (D = 14cm)

displacements in comparison with on-centre listening for the same interchannel intensity ratios. However, for low frequencies, small offsets sideways do not result in considerable image displacements.

DETERMINATION OF IMAGE POSITIONS

Practical tests have been carried out to validate the theoretical predictions made above. The tests were carried out in an anechoic chamber with a reverberation time of less than 0.25s for all frequencies down to 125Hz. The signal used was a 1/3-octave pink random noise generated by a signal noise generator in conjunction with a bandpass filter set (Bruel & Kjaer type 1402). This was fed into the two loudspeaker cabinets, each housing a single type 8P unit produced by Goodmans Loudspeakers Limited and ten subjects participated in the test. The tests were carried out for 15cm and 75cm off-centre listening positions using the geometrical layout of Fig.1.

Each subject occupying the specified off-centre position and facing directly forward was asked to specify image positions along the stage width using the dimensioned bar placed across the stage. Interchannel intensity difference was introduced between the channels by using an amplitude-control circuit. Average practical results are shown in Table 2. The average image displacement curves are shown in Fig.5 with the critical curves for the 250Hz signal. Reasonable agreement is seen to exist between theory and practice.

Frequency (Hz)	Offset (cM)	R/L	Image linear position, LL (cm)	Image position/ stage width, LL/SW
250	15	1.0	17.5	0.076
		0.8	31.875	0.138
		0.5	63.75	0.277
		0.3	92.5	0.402
		0.1	115	0.5
250	75	1.0	90	0.39
		0.8	104.375	0.454
		0.5	114.375	0.4973

Table 2. Average results: image localization in off-centre listening positions.

It is worth noting that for the 75cm off-centre movement, besides the marked displacement of the curve, most subjects reported that the position of the image became very vague. This is in agreement with the theoretical analysis, that if the offset sideways is such that the head becomes immersed in more than one interference lobe, the image could be perceived as diffused because of the antiphase nature of adjacent lobes. For a 250Hz signal, a 75cm offset sideways will bring the head in contact with more than one interference pattern, since $\lambda/2 < 75$cm.

IMAGE ELEVATION

In stereophonic sound reproduction, the phenomenon of image elevation above the speaker baseline has received great attention over the years [3,5,7]. When the listener is very close to the speaker base line, this phenomenon becomes very pronounced and central image could be perceived as coming directly from above the head.

Although image elevation has been widely reported in subjective experience, no sound theoretical explanation has been put forward for it. Image elevation in stereophony is a peculiar phenomenon and should not be expected to occur and the answer to why this is so can be found by examining the nature of the reconstructed wavefront along the axis passing through the centre of the head of a listener in the median plane.

Consider Fig.6, for deducing the wavefront $H_2(x,z)$ due to loudspeakers LS and RS located in the X−Z plane. The wavefront reconstructed by the two loudspeakers is given as:

$$H_2(x,z) = L \exp jk\,[x \sin\theta_0 + z\cos\theta_0] + \\ = R \exp jk\,[-x\sin\theta_0 + z\cos\theta_0] \quad (10)$$

$$H_2(x,z) = \exp jk\,z\cos\theta_0[L \exp(jk \times \sin\theta_0) \\ + \quad R\exp(-jk\times\sin\theta_0)] \quad (11)$$

The term in the square brackets of equation (11) is equivalent to the wavefront produced by the virtual source located in a direction of α degrees, along the X-axis. The image position can be deduced as [1,3].

$$\sin\alpha = [(L-R)/(L+R)]\sin\theta_0 \quad (12)$$

or

$$\tan\alpha = [(L-R)/(L+R)]\sin\theta_0. \quad (13)$$

Equation (13) is applicable if a better accuracy is required[1].

The wavefront due to the virtual source located in the direction α and elevated by an angle of β, in two-dimensional form can be expressed as:

$$H_2(x,z) = [\exp(jk\times\sin\alpha).\exp(jk\,z\cos q)] \quad (14)$$

In Fig.6, the following relationships exist

$$\cos q = e/f \quad (15)$$

$$\cos\alpha = e/d \quad (16)$$

$$\cos\beta = d/f \quad (17)$$

Therefore

$$\cos q = \cos\alpha\cos\beta. \quad (18)$$

Hence equation (14) becomes

$$H_2(x,z) = [\exp(jkx\sin\alpha).\exp(jk\,z\cos\alpha \\ \cos\beta)] \quad (19)$$

Equating equations (11) and (19) and neglecting the x-directional term, as it does not contribute to image elevation, we have

$$\exp(jkz\cos\theta_0) = \exp(jk\,z\cos\alpha\cos\beta)$$

$$= \exp(jk\,z\cos\beta\sqrt{1-\sin^2\alpha})$$

$$= \exp(jk\,z\cos\beta\sqrt{1-[(L-R)/(L+R)]^2\sin^2\theta_0}) \quad (20)$$

Therefore

$$\cos\beta = \frac{\cos\theta_0}{\sqrt{1-[(L-R)/(L+R)]^2\sin^2\theta_0}} \quad (21)$$

Equation (21) gives an indication of image elevation above the speaker's base line for an image position defined by the interchannel intensity ratio.

If L = R, then $\beta = \theta_0$ and the elevation is maximum. As L/R decreases, the elevation decreases until it reaches a minimum when one speaker is radiating and the image becomes located at that speaker. This is in good agreement with earlier reported subjective experiences. Figure 7 shows the pattern of image elevation for image positions along the stage width. If the subject is close to the speakers baseline – that is if θ_0 approaches 90°, then the central image elevation approaches 90° and the virtual image tends to appear directly overhead. This is what is experienced in practice[3].

The wavefront reconstruction theory has therefore been used to explain the phenomenon of image elevation in stereophonic sound reproduction. The amount of elevation perceived will ultimately depend on the listening distance for a given speaker separation.

The parameters of the wavefront along the Z-axis in Fig.6 could also be interpreted as a depressed image. However, subjective experience indicates that the stereophonic image is always located above the speaker baseline. The way in which the ear/brain combinations interprets this information in the Z-axis such that an elevated image is perceived is not yet fully understood.

REFERENCES:

1. Bennett, J.C., Barker, K., Edeko, F.O.: A new approach to the assessment of stereophonic sound system performance. *J.A.E.S.*, vol.33, 1985, pp.314-320.
2. Edeko, F.O.: Image localization and interchannel phase difference. *Electronics and Wireless World*, vol. 93, 1987, pp799-802.
3. Leakey, D.M.: some measurements on the effect of interchannel intensity and time difference in two channel sound systems. *J.A.S.A.* Vol.31, no.7, 1959, pp.977-986.
4. Clark, H. M. Dutton, G.F., Vanderlyn, P.B.: The stereophonic recording and reproduction systems, *The Proceedings of I.E.E.*, vol. 104, 1957, pp.417 - 431.
5. Blauert, J.: "Spatial Hearing", MIT Press, 1983.
6. Bauer, B.B.: "Phasor analysis of some stereophonic phenomenon", *J.A.S.A.*, Vol.33, 1961, pp.1536 - 1539.
7. Roffler, S. K. Butler R.A.: Factors that influence the localization of sound in the vertial plane, *J.A.S.A.*, vol. 43, no.6, 1968, pp.1255 - 1259.

Dr Edeko is a lecturer in the Department of Electrical and Electronic Engineering at the University of Benin, Nigeria

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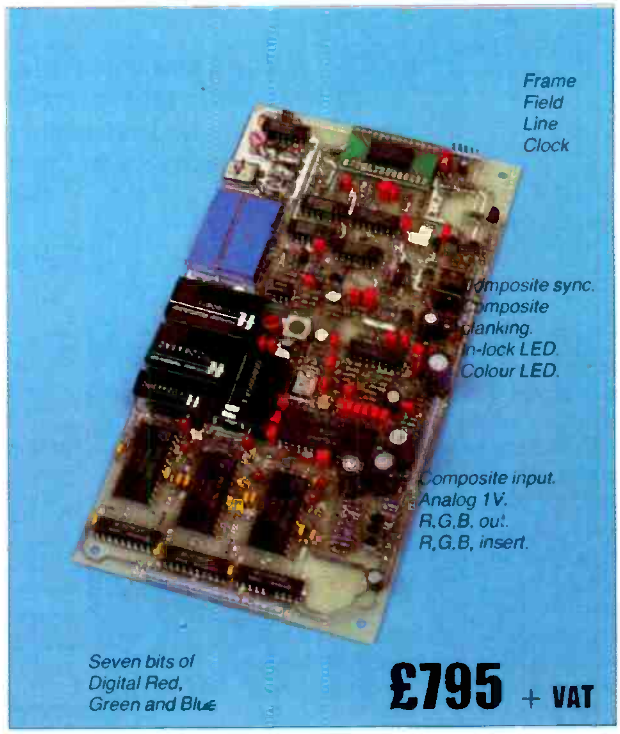

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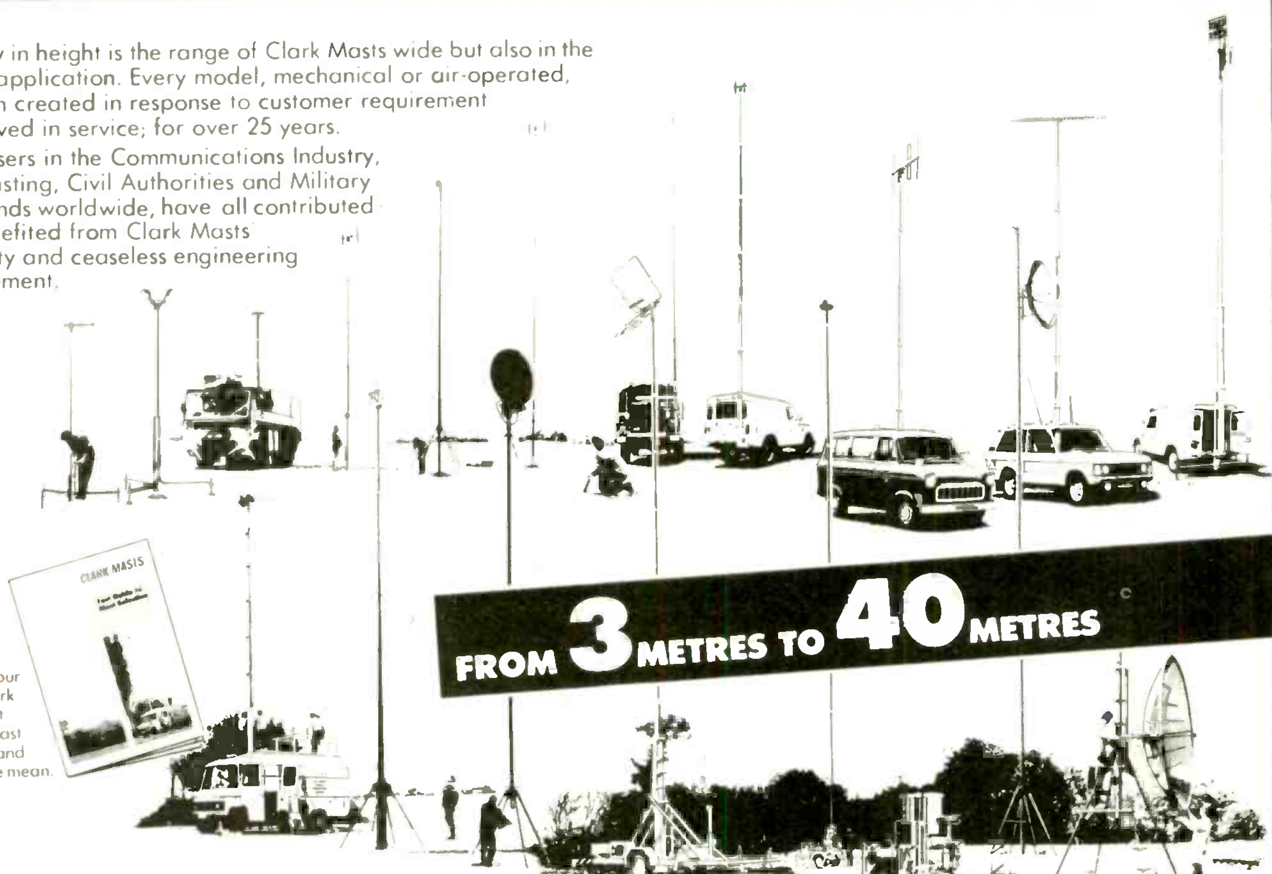

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A new technique in o.t.d.r.

Using a new correlation technique, time-domain reflectometry measurements of optical fibre are obtained 64 times faster than is possible with conventional single-pulse methods, given the same laser, receiver and optical coupling.

STEVE NEWTON

The optical time-domain reflectometer, o.t.d.r., is the primary measurement instrument for the single-ended characterization of optical fibre. By timing the arrival of backscattered and backreflected light generated by optically probing the fibre under test, the magnitudes and locations of faults and reflections can be determined, and the propagation characteristics of the fibre can be estimated.

During the past several years, o.t.d.r. measurement has become more difficult. As users of fibre have progressed to longer transmission wavelengths because of lower loss, and as higher-quality fibre has become available, there is less backscattered light to be measured. Furthermore, the dominant use of single-mode fibre makes the coupling of the probe signal less efficient, and results in a smaller fraction of what little light *is* scattered being captured by the fibre and guided back to the measurement instrument. At the same time, the long lengths of the fibre systems that are being installed require that, in addition to the high sensitivity needed to measure extremely low levels of backscattered light, o.t.d.rs must also have a very large dynamic range.

Yet, despite their wide usage during the past several years, surprisingly few fundamental changes in o.t.d.r. design have been seen. While incremental changes such as the use of higher power lasers and the parallel averaging of all data points on a single probe shot have provided some improvement, they have been unable to remedy a limitation that is funadamental to all conventional o.t.d.r. designs: the trade-off between signal-to-noise ratio (which determines dynamic range and measurement time) and response resolution.

This article describes a new approach to optical time-domain reflectometry that applies spread-spectrum techniques, such as those used in radar, to increase dynamic range and dramatically reduce the required measurement time, *without* sacrificing resolution. The resulting performance is the best yet reported for a practical system.

CONVENTIONAL OTDR MEASUREMENT

An o.t.d.r. is an instrument that characterizes optical fibre by launching a probe signal into the fibre under test and detecting, averaging, and displaying the return signal. The distance to a given feature is determined by simply timing the arrival of that part of the return signal at the detector.

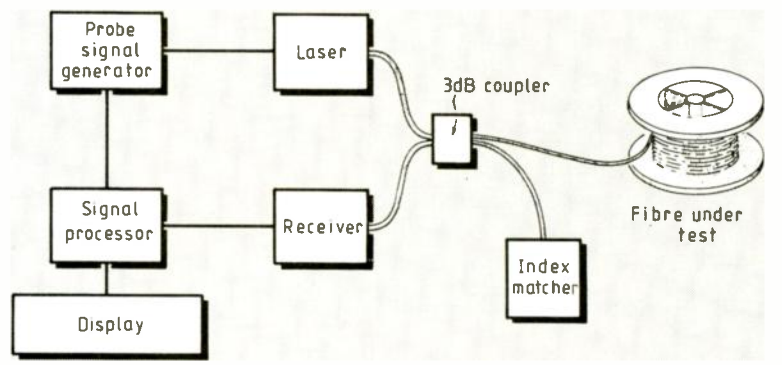

Fig.1. Block diagram of an optical time-domain reflectometer.

Figure 1 is a block diagram of a generic o.t.d.r. An electronic-probe signal generator modulates the intensity of a laser. In a conventional o.t.d.r. the probe signal is a single square pulse; in portable instruments, a semiconductor laser is used as the source. Output of the laser is coupled into the fibre under test using a beam splitter or, as shown in Fig. 1, a 3dB directional coupler. In the case of a fibre coupler, unused output of the directional coupler must be terminated by a method such as refractive-index matching in order to prevent the probe signal from being reflected directly back into the receiver.

The return signal from the fibre under test is coupled to the receiver through the beam splitter or coupler. It is important that this beam splitter be polarization independent, otherwise polarization variations in the backscattered signal will appear to be changes in the power. The amplified signal is then processed, usually by averaging, before being transferred to the display.

BACKSCATTERING IMPULSE RESPONSE

The main object of o.t.d.r. measurement is to determine the backscattering impulse response of the fibre under test. This is strictly defined as the response of the fibre to a probe signal which is an ideal delta-function impulse, as detected by an ideal receiver at the same port into which the probe was injected. Since the physical processes that generate it are all linear, the backscattering impulse response is indeed a true impulse response, and the fibre can be treated as a linear system or network.

In practice, however, the signal that is displayed is not the backscattering impulse response itself, but rather a smoothed version of it. The smoothing is due to the effects of the non-zero duration of the probe pulse and receiver response, and will be described in more detail later.

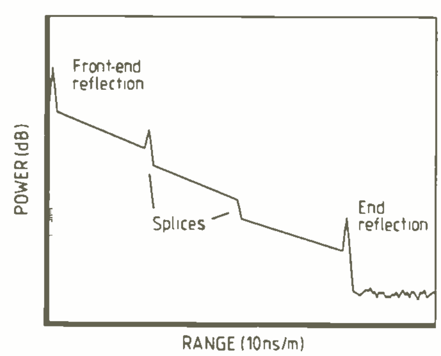

Fig.2. Example of a fibre-backscattering impulse response.

Figure 2 illustrates what a typical measurement might look like. The measured response is plotted on a logarithmic scale, in decibels. Although the data is acquired as a function of time, it is displayed as a function of distance using a conversion factor which approximately equals 10μs/km – the 'round-trip' propagation delay of light in fibre.

An ideal fibre without breaks, splices, or reflections would be displayed as a perfectly straight line, indicative of the exponential decay due to propagation loss. The measured response typically exhibits two kinds of features: positive spikes that are due to reflections, and relatively smooth exponentially decaying signals that are due to Rayleigh backscattering. These backscattering curves can exhibit discontinuities, which may be either positive or negative, depending on the physical causes of that particular feature.

PHYSICAL ORIGINS OF THE BACK-SCATTERING IMPULSE RESPONSE

To interpret the response that is measured correctly, the physical situations that give rise to the observed features must be identified and understood. Some of these situations are illustrated in Fig.3. All of the features that comprise the backscattering impulse response are derived from either of two physical effects: Fresnel reflections and Rayleigh scattering.

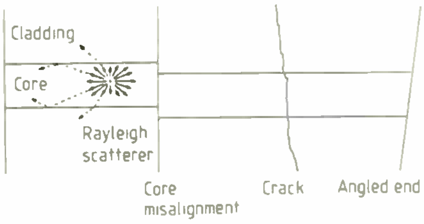

Fig.3. Physical origins of major features of backscattering impulse response.

Fresnel reflections. Just as an electrical time-domain reflectometer measures mismatches and discontinuities in electrical impedance, an optical t.d.r. measures discontinuities and mismatches in the optical refractive index. Such a mismatch results in what is commonly called a Fresnel reflection, whose magnitude is given by:

$$\frac{P_{refl}}{P_{inc}} = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2,$$

where P_{refl} and P_{inc} are the reflected and incident optical powers respectively, and n_1 and n_2 are the indices of refraction at the discontinuity.

Fresnel reflections commonly occur at connectors, mechanical splices, and unmatched ends of a fibre cable. If the interface is between fibre and air, as it might be at a junction where an air gap exists or at the end of a 'perfectly' broken fibre (a clean break perpendicular to the optical axis), the reflection should be around 3.4% (−14.7dB) of the incident power.

In practice, however, reflections having just this magnitude are not often seen. For example, the measured reflections at glass/air interfaces can be much smaller if the fibre is dirty or not cleanly broken in the vicinity of the core. Even a clean, flat fibre end can exhibit low reflection if it is angled with respect to the optical axis. In these cases, the light is reflected or scattered at an angle that is too large for it to be captured in the fibre core and guided back to the input. For example, if the end of a single-mode fibre is cleaved at an angle of only 6° the reflected power that is guided back to the input is 69dB down from the incident power.

On the other hand, conditions can exist that actually enhance Fresnel reflections or that make such reflections difficult to suppress. For example, a gap at a connector joint may form an etalon* between the fibre faces which, if the spacing is right, can lead to a resonant enhancement of the reflection. Also, the polishing of a fibre end appears to cause its refractive index to increase (perhaps by more than 50%) in a thin layer near its surface. This can lead to an index discontinuity within the fibre itself, resulting in the presence of a reflection regardless of the condition of the end surface.

The ability of o.t.d.rs to measure the magnitude of Fresnel reflections will be increasingly important in the future as more and more narrow line-width laser sources are installed in coherent and/or wavelength-multiplexed transmission systems. The reason is that these sources exhibit serious spectral instabilities when large reflections are present. Occasionally, other situations may arise wherein it is important to know the magnitude of Fresnel reflections. In these cases, an o.t.d.r's ability to measure reflections will prove to be valuable.

In most cases, however, the magnitudes of Fresnel reflections in the backscattering impulse response have little or no significance. This may seem surprising since reflection peaks appear to be the most dramatic features of the measured signal. However, the present or absence of a reflection peak at a connector or splice does not by itself give an indication of the quality of the joint. That and other information are best determined by observing changes in the level and slope of the part of the response that is due to Rayleigh scattering.

Rayleigh scattering. Whereas electrical t.d.rs measure only discrete reflections, o.t.d.rs also measure a low-level background of backscattered light whose decay is ideally proportional to that of the probe signal that travels along the fibre. In principle this allows the propagation loss of a fibre segment to be measured by observing the slope of the backscattering impulse response. In practice, this is usually the case, however some care must be taken in making this interpretation if a variation in backscattering parameters as a function of distance is suspected (i.e. if the fibre does not scatter uniformly along its length).

Rayleigh scattering is the dominant loss mechanism in single mode fibre. It occurs because of small inhomogeneities in the local refractive index of the fibre, which re-radiate the incident light in a dipolar distribution. In single-mode fibre, only a very small fraction (approximately 10^{-3}) of the scattered light falls within the small capture angle of the fibre and is guided back to the input.

One of the main challenges of an o.t.d.r. measurement is that the backscattered signal is very weak. The dependence of Rayleigh scattering on wavelength is $1/\lambda^4$, and has motivated fibre system designers to use longer transmission wavelengths: typically 1.3μm (the wavelength of minimum dispersion) or 1.55μm (the wavelength of minimum loss). Unfortunately, at these wavelengths there is little scattering to be captured, guided in the backward direction, and detected by an o.t.d.r. For example, the detectable backscattered power generated by a 1μs probe pulse is roughly 2000 times smaller (−33dB) than what would be reflected by a 3.5% Fresnel reflection at the same location.

Not only must an o.t.d.r. be able to measure these small signal levels, it must also be able to detect small *changes* in these small signal levels of the order of ±0.05dB (±1%). For example, connectors and splices in many fibre transmission systems are required to have insertion losses of the order of 0.1dB. If the total allowable loss is exceeded, the faulty junction(s) must be identified. In an o.t.d.r. measurement, a lossy junction would appear as an abrupt lowering of the backscattering level. Such a discontinuity could be caused by a misalignment of the fibres at a splice or connector, where core offsets of as little as 1μm can result in substantial losses. Another source of loss might be a bend in the fibre which is sharper than its allowable bend radius, causing some of the guided light to be radiated into the cladding and lost. In this case, the o.t.d.r. would also measure a discontinuity. Finally, in the case of a catastrophic fault, such as a break in the fibre, the backscattering impulse response would abruptly drop into the noise.

On rare occasions, when a fibre is joined to a lossier fibre, the measured backscattering level can actually *increase* abruptly, followed by a more rapid decay. This points out once again that the backscattering impulse response does not always precisely indicate what happens to a forward travelling signal (such a signal would certainly not experience gain at the junction!). However, in the great majority of cases, and with proper interpretation, the backscattering impulse response measured by an o.t.d.r. can present an accurate and useful picture of the propagation conditions along an optical-fibre cable.

Applications. An o.t.d.r. measurement of a fibre's backscattering impulse response contains information that can be useful for many different purposes. Indeed, o.t.d.rs are used in a wide variety of applications. Some of these applications are.

- Fibre length determination
- Fibre characterization
- Active splicing during installation
- Splice and connector maintenance
- Detection and location of catastrophic faults
- Security: detection and location of taps

* Interferometer comprising an air film between two half-silvered quartz plates.

IMPROVED OTDR MEASUREMENT

Performance of an optical time-domain reflectometer is dramatically improved using a new correlation technique that employs codes with complementary autocorrelation properties. Using this technique experimentally, equivalent results were obtained over 64 times faster than is possible with a conventional single-pulse measurement using the same laser, receiver, and coupling optics. Alternatively, a 9dB two-way range improvement was obtained in the same measurement time.

- Component testing
- Network testing
- Sensing: interrogation of optical sensors

PERFORMANCE PARAMETERS

Performance of an o.t.d.r. can be specified using a set of parameters that describe the quality of the measurement. Figures 4 and 5 depict some of the key features of a backscattering impulse response that can be used to define and describe these key performance parameters.

Dynamic range. The dynamic range is a measurement of the range of optical power levels over which useful measurements of backscattering impulse response can be made. It is usually defined as the range from the initial backscattering level of the noise, Fig.4. Since the initial backscattering level

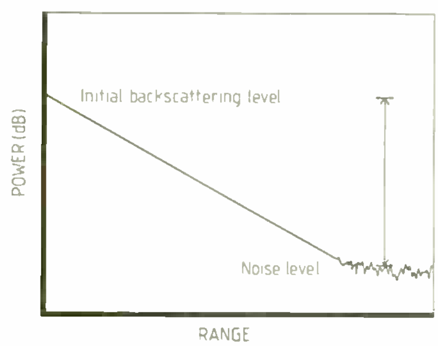

Fig.4. Dynamic range is the difference in power levels between initial backscattering and noise.

depends on the probe pulse width and the attenuation coefficient of the fibre, these parameters, or at least the operating wavelength, should be stated when specifying the dynamic range. At the low end of the range, some criterion for the point where the signal hits the noise must be stated as well. The level of peak noise and the level of r.m.s. noise are used most frequently.

Two different terms have evolved to describe dynamic range, which is always expressed in optical decibels. Dynamic range that is actually measured by the instrument, called two-way dynamic range, corresponds to the difference in actual optical power levels. The second term, one-way dynamic range, is equal to half of the two-way dynamic range. It is commonly used to specify instrument performance because it allows the user to simply divide the one-way range by the propagation loss of the fibre (always specified as one-way loss) to estimate how far into the fibre one can expect to see. For example, suppose that the initial backscattered power from a 1μs probe pulse is measured to be 20nW (–47dBm) and that the noise equivalent power after a specified averaging time is 2pW (–87dBm). The range of optical powers measured (two-way dynamic range) is 40dB, but the one-way range would be specified as 20dB. A user working with fibre having a propagation loss of 0.35dB/km would see the backscattering signal equal the noise at a distance of approximately 57km. Note that this example reflects a typical o.t.d.r. measurement.

Finally, at the risk of confusing matters further, it should be noted that optical

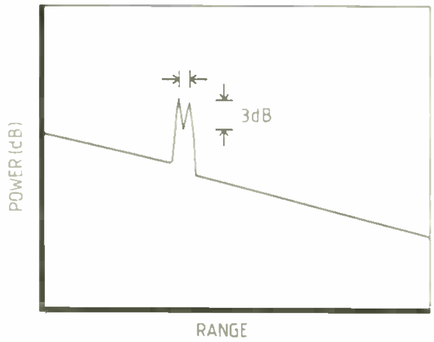

Fig.5. Response resolution is the minimum separation at which two faults can be distinguished from each other.

decibels and electrical decibels are related by a factor of two; one optical decibel is two electrical decibels. This is because the light is detected using a square-law detector which relates optical power to electrical current. Thus, the range of electrical signals measured in the preceding example is 80dB (electrical). Again, o.t.d.r. performance is always specified in terms of optical decibels.

Response resolution. The response resolution (two-point resolution) is a measure of how close two faults can be and yet still be distinguished from one another by the measurement. It can be defined as the minimum separation between two equal peaks such that the measured signal drops by some arbitrary fraction of the peak height (3dB, for example) between the two features, thereby allowing them to be distinguished, Fig.5. Response resolution is directly related to the probe pulse width.

Amplitude sensitivity. The amplitude sensitivity specifies the minimum amplitude variation that can be detected at a certain location on the measured signal, Fig.6. It is typically limited by noise, but may also be limited by measurement deficiencies that are optical (e.g. polarization effects) or electrical (e.g. digitization errors).

Linearity. The linearity of a measurement can be expressed in terms of the deviation of the amplitude sensitivity envelope from a straight line when an 'ideal' fibre having a perfect exponential decay is measured. It is usually expressed in dB/dB. Deviations from linearity can be caused by non-ideal behaviour of the receiver or analogue-to-digital converter, for example.

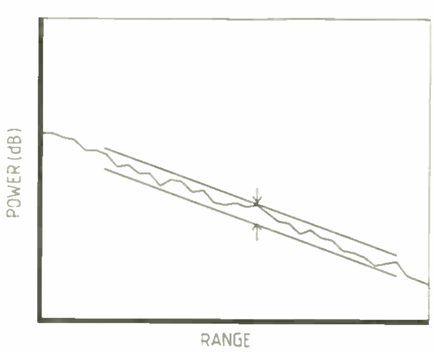

Fig.6. Amplitude sensitivity is the minimum amplitude variation that can be detected at a given point on a measured signal.

Measurement time. The measurement time required to achieve a given dynamic range capability is a basic and essential specification of the performance of an o.t.d.r. Unfortunately, it is routinely omitted from o.t.d.r. dynamic-range specifications. As will be described shortly, the dynamic range and the averaging time are intimately related and must always be specified together.

Range resolution. The range resolution is a measure of the uncertainty of the absolute position of a given feature, and is usually directly related to the sampling period. If the range resolution of a measurement is 10m and the fibre under test is shortened by 10m, then the measured backscattering curve will be shifted by one data point. It does *not* mean that faults 10m apart can be distinguished: that capability is specified by the response resolution.

Other specifications. A prospective user of an o.t.d.r. should use caution when encountering the terms measurement range (expressed in km), display range, and readout resolution. Measurement range is meaningless when expressed in terms of distance since it must assume a particular fibre loss, which usually isn't specified. Display range and readout resolution are often used in misleading ways that imply superior measurement capabilities. However, these terms relate to the way a given measurement is displayed, and have nothing to do with the quality of the measurement. The display range is the maximum distance that can be displayed. Readout resolution is simply the smallest resolvable interval of the display or the minimum marker increment. When judging the measurement capabilities of an o.t.d.r., and not its display capabilities, the performance specifications described previously should be sought.

S-TO-N RATIO VERSUS RESPONSE RESOLUTION

A fundamental limitation of any conventional o.t.d.r. measurement is the trade off between response resolution and signal-to-noise ratio. Increasing the signal-to-noise ratio of an o.t.d.r. measurement results in increased dynamic range in a given measurement time or, alternatively, a reduction in the number of averages required to obtain a given result.

In any o.t.d.r. measurement, the received signal s(t) can be expressed as the convolution (*) of p(t), the signal that probes the fibre, r(t), the impulse response of the receiver, and f(t), the backscattering impulse response of the fibre and the quantity that is being measured.

$$s(t)=p(t)*r(t)*f(t).$$

The response resolution of the measurement is therefore degraded according to the duration of the receiver response as well as that of the probe signal, Fig.7. In a conventional single-pulse o.t.d.r., the probe signal is simply a square pulse having duration ΔT. If $\Delta T = 1\mu s$ for example, the response resolution can be no better than approximately 100m, even with an ideal receiver. Strictly from the point of view of response resolution, it is desirable that the probe pulse

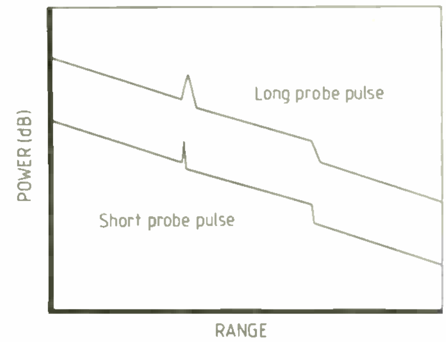

Fig.7. Differences in response resolution due to different probe pulse widths.

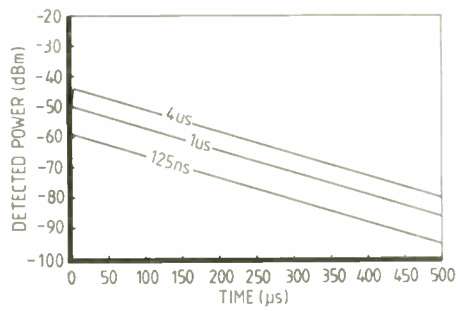

Fig.8. Differences in backscattering power level due to different probe pulse widths.

width be as small as possible.

On the other hand, the strength of the received signal is proportional to the energy of the probe signal, which is the product of the peak power and the probe pulse width, Fig.8. For an ideal fibre with constant propagation loss along its length, the detected optical power P(t) is given by,

for $0<t<\Delta T$:

$$P(t) = \frac{1}{2} S\, P_{in}\,(1 - e^{-\alpha v_g t}),$$

for $\Delta T<t<\infty$:

$$P(t) = \frac{1}{2}\, S\, P_{in}(e^{\alpha v_g \Delta T} - 1)e^{-\alpha v_g t}$$

$$\approx \frac{1}{2}\alpha v_g S P_{in} \Delta T e^{-\alpha v_g t},$$

where α is the attenuation coefficient of the fibre, v_g is the group velocity of the probe pulse, S is the backscattering capture coefficient[2] and ΔT is the probe pulse width. Clearly, in a conventional single-pulse o.t.d.r., the signal strength resulting from a single probe shot can be maximized only by increasing the peak power or the duration of the probe pulse.

Unfortunately, very high-power sources[3,4] are precluded from use in a practical system due to portability and durability requirements, which point to the use of semiconductor laser sources. The use of special high peak-power semiconductor lasers is also problematical in a practical system due to their high cost, limited lifetimes, and high drive-current requirements, the latter being undesirable when the laser is used in close proximity to a high-sensitivity receiver. Once the peak pulse power of a standard laser has been increased to its maximum practical value, the probe energy and therefore the return signal can be increased further only by making the probe pulse longer, which in turn degrades the response resolution of the measurement.

The trade-off between signal strength and resolution in a single-pulse o.t.d.r. manifests itself as a limitation in dynamic range or, alternatively, the averaging time of the measurement.

The signal-to-noise ratio in decibels of a measurement at a range z can be simply expressed by the 'o.t.d.r.-maker's formula'.

$$SNR = P_{init} - 2\alpha z - \sigma + 1.5N_{oct}$$

where P_{init} is the initial value of the backscattered power given by,

$$P_{init} = \frac{1}{2}SP_{in}(1 - e^{-\alpha v_g \Delta T}) \approx \frac{1}{2}\alpha v_g S P_{in} \Delta T,$$

where σ is the receiver noise equivalent power in dBm, and N_{oct} is the number of probe shots expressed in octaves (i.e. $N_{oct} = \log_2$ (N×shots)). For example, each time the number of averages is doubled, the signal-to-noise ratio improves by $\sqrt{2}$, or about 1.5dB, provided that true averaging is used. (Some o.t.d.rs use exponential averaging to save memory. Exponential averages do not converge, and can lead to false results after long averaging times.)

The o.t.d.r. maker's formula makes clear the dependence of the measurement range and measurement time on the signal-to-noise ratio. The trade-off between the signal-to-noise ratio and the response resolution is therefore an important and fundamental limitation on the overall performance of a conventional single-pulse o.t.d.r.

SPREAD-SPECTRUM TECHNIQUES

Spread-spectrum techniques such as correlation offer the possibility of providing measurements with improved signal-to-noise ratio without sacrificing response resolution. Such techniques are commonly used in radar[5] and other peak-power limited systems where increases in the transmitted energy would otherwise result in degraded resolution.

One way of applying correlation to o.t.d.r. measurements is to correlate (*) the detected signal s(t) with the probe signal p(t).

$$s(t)*p(t) = [p(t)*r(t)*f(t)]*p(t)$$
$$= [p(t)*p(t)]*[f(t)*r(t)]$$

To the extent that the autocorrelation of the probe signal approximates a delta function, the fibre backscattering response f(t) can be accurately recovered, subject (as always) to the response of the receiver.

$$[p(t)*p(t)]*[f(t)*r(t)] \approx \delta(t)*[f(t)*r(t)]$$
$$= f(t)*r(t)$$

In this case, the duration of the autocorrelation of the probe signal determines the response resolution and not the duration of the probe signal itself, which may be long and energetic.

The idea of using correlation in o.t.d.r. measurements is not new. A number of proposals and experimental demonstrations have been published previously[6-9]. In each of these experiments, pseudo-random codes were used to probe the fibre under test. More recently, the use of Barker codes in connection with a coherent optical t.d.r. was demonstrated[10]. However, none of the coded probe signals reported to date has proved useful in practical o.t.d.rs since, even under ideal conditions, their autocorrelations exhibit side lobes (typically <20dB below the peak) that are not sufficiently low to avoid distortion in the neighbourhood of large reflections and discontinuities, which may exceed 20dB in magnitude. Much of this work seems to have been abandoned, since a finite probe signal with zero autocorrelation sidelobes has not been found.

COMPLEMENTARY CODES

The new method described here realizes the full advantage of correlation by probing and correlating with pairs of probe signals that have complementary autocorrelation properties. These probe signals are the complementary codes[11] which were first introduced by M. J. E. Golay in the late 1940's as a method of improving the performance of multi-slit spectrometers. Golay codes have the following property – if A and B are an L-bit complementary-code pair then,

$$(A*A) + (B*B) = 2L\delta(t).$$

The unique autocorrelation properties of Golay codes are shown graphically in Fig.9. Individual autocorrelations of each one of a 64-bit complementary-code pair are shown in the upper two plots. Each of the individual codes consists of a pattern of ±1's. The value of each of the autocorrelation peaks is equal to the number of bits in the individual code. Each of the individual autocorrelations also

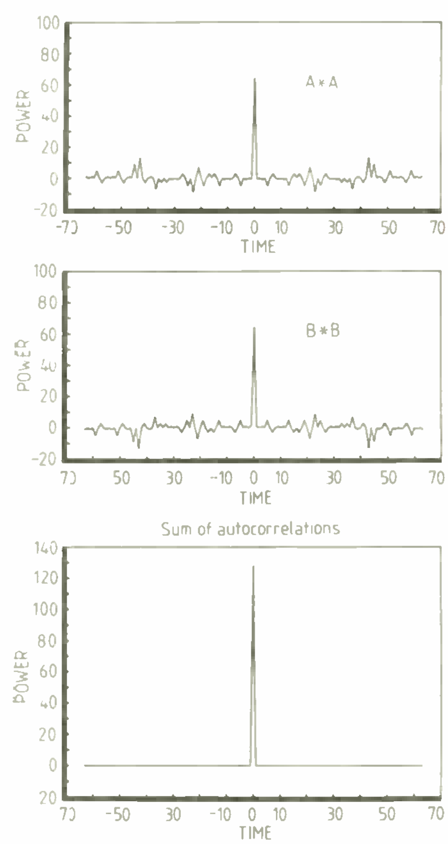

Fig.9. Upper curves are individual autocorrelations of each half of a 64bit Golay code pair. The sum of these is shown in the lower curve.

exhibits side lobes that are up to 10% of the peak height. However, when the autocorrelations are added together, the peaks add together to a value of 2L and the side lobes cancel exactly!

It is this contribution of all of the bits to the autocorrelation peak along with the complete cancellation of the side lobes that allows the correlation technique to work in practice. In designing a practical system of this kind, it is essential to work with an autocorrelation function that is perfect in principle, since finite side lobes will always exist in a real, non-ideal system. Using complementary codes, the sidelobes in a real system can be low enough so that the full advantage of correlation can be realized.

SIGNAL PROCESSING

In order to realize the full correlation gain offered by the use of complementary codes as probe signals, a novel signal processing sequence is required. The problem is that the complementary codes are bipolar and since the o.t.d.r. makes use of square-law detection, there is no way to probe the fibre with negative signals.

The solution is to transmit the bipolar codes on a bias which is equal to half of the available peak power. The fibre is probed by successive groups of four probe 'shots', this sequence being comprised of each member of an L-bit Golay-code pair and its one's complement. By subtracting the measured backscattering signals in pairs, the component of the signals generated by the bias is cancelled, whereas the component generated by the codes is reinforced. By correlating these differences with their respective codes and summing the correlation results, the net processed signal is equal to,

$$4L\left[f(t)*\sqcap\left(\frac{t}{\Delta T}\right)*r(t)\right],$$

where,

$$\sqcap\left(\frac{t}{\Delta T}\right)$$

represents a single bit of the code as square pulse of duration ΔT. Thus, in the time it takes a conventional single-pulse o.t.d.r. to make four measurements, this coded probing scheme effectively makes 4L measurements, with every transmitted bit contributing to the result.

In fact, the concept of each bit of the coded probe signal making a contribution corresponds exactly to what is happening during a measurement. When an o.t.d.r. probes a fibre with codes, it simultaneously measures many backscattering curves, each generated by an individual bit. As Fig. 10 indicates, the raw signal that is detected is the superposition of these backscattering curves. While the raw signal is unrecognizable as the fibre response in this form, the signal processing effectively rearranges the superposed signals to recover the fibre impulse response with the resolution of a single bit. At the same time, the extra energy that is injected into the fibre and subsequently detected results in a signal-to-noise improvement proportional to $\sqrt{L}$.

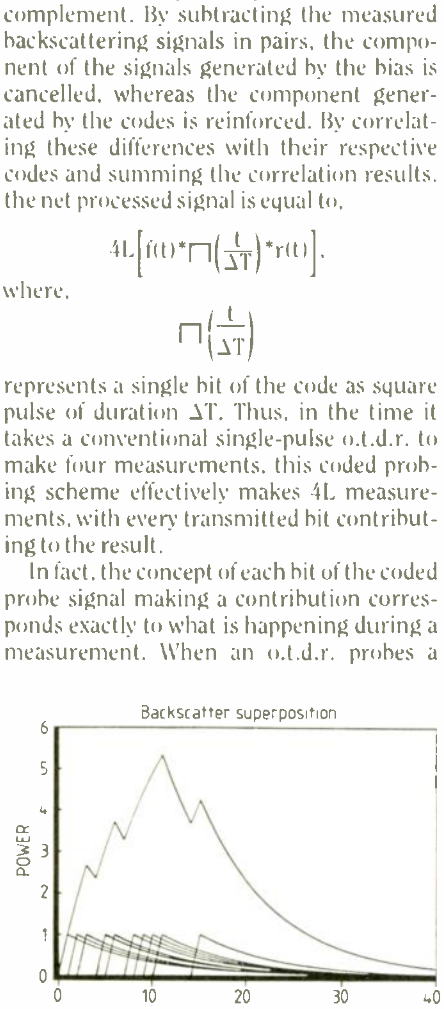

Fig.10. Each bit of the probe signal generates a backscattering signal. Their superposition is what is detected and processed.

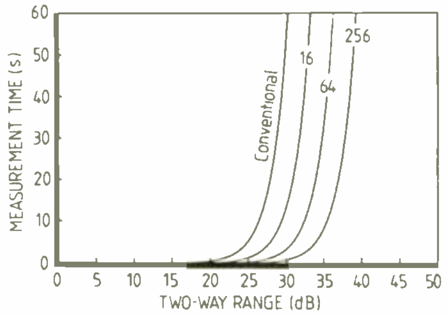

Fig.11. Time to measure 0.1dB faults versus two-way range for a conventional o.t.d.r. and a complementary-correlation o.t.d.r. using code lengths 16, 64 and 256.

CORRELATION GAIN

The effect of correlation on the key performance parameters of an o.t.d.r. is given by the 'correlation o.t.d.r.-maker's formula',

$$SNR = P_{init}-2\alpha z-\sigma+1.5(N_{oct}+L_{oct}),$$

where the parameters are the same as in the conventional o.t.d.r.-maker's formula, except for the addition of the term L_{oct} which is the code length expressed in octaves (i.e. $L_{oct}=\log_2 L$). As with a conventional single-pulse o.t.d.r., the signal-to-noise ratio is improved by 1.5dB each time the number of averages is doubled. In the case of the complementary correlation o.t.d.r., however, the signal-to-noise ratio improves by an extra factor of 1.5dB for each octave of code length in the probe signal. This equation also explicitly shows that each bit of the probe signal effectively provides an extra average of the data, thereby reducing the measurement time.

When comparing the performance of the complementary-correlation o.t.d.r. (c.c.o.t.d.r.) to that of a conventional single-pulse o.t.d.r., it has been shown that the correlation technique allows L more effective averages in the same measurement time. To make a fair comparison, however, it should be noted that the conventional probe is a single pulse at the full peak power of the laser, whereas for the coded probe each bit has an amplitude of only half of the peak power due to the bias that it must ride on. In terms of the o.t.d.r.-maker's formula, this means that P_{init} is 3dB larger for a conventional measurement than for a coded one that uses the signal processing scheme described previously. As a result, performance equivalent to that of a conventional optical t.d.r. is obtained in the complementary-correlation o.t.d.r. by using a code length of $4(L_{oct}=2)$.

Nevertheless, the relative gain to be realized using the complementary-correlation o.t.d.r. is substantial, Fig. 11. By solving the 'c.c.o.t.d.r.-maker's formula' for the number of probe shots and assuming a 1kHz repetition rate and 1µs bits, the time required to achieve an amplitude sensitivity of 0.1dB (signal-to-noise ratio of 17dB) is plotted as a function of two-way range. The curves are plotted for a conventional o.t.d.r. and for a complementary-correlation o.t.d.r. using code lengths of 16, 64, and 256.

Performance advantage of the complementary-correlation o.t.d.r. can be seen in two ways. By comparing the conventional result with the result of a 256bit code measurement after 60 seconds of measurement time, the complementary-correlation o.t.d.r. is seen to measure the same sensitivity 9dB farther into the fibre. In practice this might correspond to a range improvement of 10-18km, depending on fibre loss. Furthermore, the measurement range and amplitude sensitivity obtained with a conventional o.t.d.r. in one minute of measurement time (0.1dB sensitivity at 30.5dB) is obtained with the complementary-correlation o.t.d.r. using 25bit probe codes in less than one second.

Experimental results and details of the instrument incorporating this technique will be given in a subsequent article. Steven A. Newton is with Hewlett Packard in Palo Alto, California.

References

1. S.D. Personick, Photon probe: An optical-fibre time domain relfectometer, *Bell Syst. Tech. J.* 56, 355(1976).
2. E. Brinkmeyer, Analysis of the Backscattering Method for Single-Mode Optical Fibers, *J. Opt. Soc. Am.* 70, 1010 (1980).
3. M. Nakazawa, M. Tokuda, K. Washio, and Y. Morishige, Marked extension of diagnosis length in optical time domain reflectometry using 1.32µm YAG laser, *Electron. Lett.* 17, 783 (1981).
4. K. Noguchi, Y. Murakami, K. Yamashita, and F. Ashiya, 52-km-long single-mode optical fiber fault location using the stimulated Raman scattering effect, *Electron. Lett.* 18, 41 (1982).
5. F.E. Nathanson, *Radar Design Principles*. New York: McGraw-Hill (1969).
6. K. Okada, K. Hashimoto, T. Shibata, and Y. Nagaky, Optical cable fault location using correlation technique, *Electron. Lett.* 16, 629 (1980).
7. P. Healy, Pulse compression coding in optical time domain reflectometry, *Proc. 7th Eur. Conf. Opt. Commun.*, Copenhagen, 5.2-1 (1981).
8. M. Zaboli and P. Bassi, High spatial resolution OTDR attenuation measurement by a correlation technique, *Appl. Opt.* 22, 3680 (1983).
9. J.J. Bernard, J. Ducate, Y. Gausson, J. Guillon, and G. Le Blevennec, Field portable reflectometer for single-mode fiber cables, *Proc. 10th Eur. Conf. Commun.*, Stuttgart, 84 (1984).
10. J.P. King, D.F. Smith, K. Richards, P. Timson, R.E. Epworth, and S. Wright, Development of a coherent OTDR instrument, *IEEE J. Lightwave Tech.* LT-5, 616 (1987).
11. M.J.E. Golay, Complementary series, *IRE Trans.* IT-7, 82 (1961).

8051 Project....?

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Fast risc processor

Because of the way that microprocessors are designed, their performance on paper is difficult to achieve in practice since they communicate with other chips in a less than perfect manner.

One way of relieving this problem, adopted by AMD for their new AM29000 risc processor, is to use an efficient external interfacing scheme consisting of three 32bit buses – one for addresses, one for data and one for instructions.

Having separate buses removes gating delays, resulting in an increase in the time available for accessing external devices. One important advantage of this feature is that memory costs can be reduced by replacing expensive static rams with video dynamic rams.

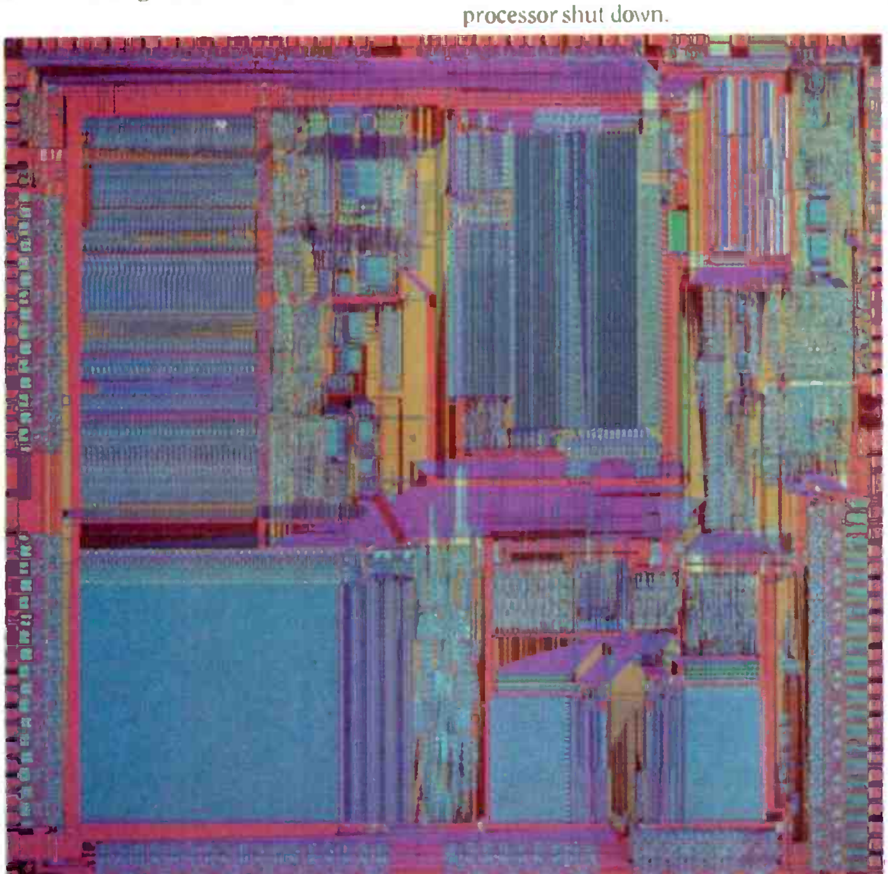
Apart from a 17 Mips sustained execution speed, the 29000 has 192 general-purpose 32bit registers and, despite the fact that it is a reduced-instruction-set processor, it has 115 instructions. The reason for this large instruction set is that the device is intended either as a general-purpose processor for use in workstations, etc., or as an embedded controller for specific applications like controlling a laser printer.

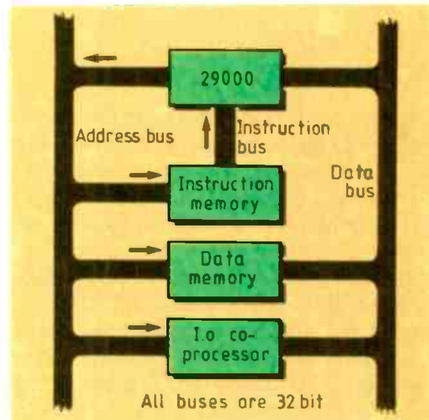
Of the 192 registers, 128 are local registers accessed through indirect addressing and 64 are global registers accessed by absolute addressing. Every register is capable of storing data or addresses and is accessible by any instruction: with the exception of load-and-store operations, all 29000 operations are intended for register-to-register manipulation.

Implementation of a run-time stack cache is possible by addressing local registers from the stack pointer. This mode allows parameters to be passed to a function or procedure without accessing external memory. As a result, procedure calls/returns can be executed on average five to ten times fewer cycles than is possible with external-stack processors, says AMD.

Alternatively, register banking provides fast context switching by dividing the local registers into eight banks of 16 registers. These banks can hold processor status information and variables for up to eight different tasks that can be switched between in as few as 17 cycles.

For use in fault-tolerant systems, the processor has a master/slave facility. To use this facility two processors are connected in parallel, one operating in master mode and the other in slave mode. The processor in master mode operates normally while the other, in slave mode, simply follows the operation of the master. If the master processor does not do what the slave would have done in the same circumstances, the condition is flagged and the system can be shut down. A more elegant solution is to use more than two processors so that the system can continue to run with only the offending processor shut down.





Three-bus architecture

Simulation ready for new 17 Mips risc processor

Microprocessor technology is advancing so rapidly now that provisional details of at least one new device are always available. As a result, designers are often faced with a difficult choice: they can either take the safe option of using an existing device, or they can take a risk and design their system from preliminary data on the very latest processor.

Since microprocessors are designed on computers, it is possible for manufacturers to produce simulation programs as soon as the design work is completed, but before the manufacturing process begins. Making software simulators available to designers helps them decide whether or not the new processor is worth waiting for. Seeing how an existing program will run on a simulator is much more useful than an evaluation worked out from instruction-time specifications and benchmark-test data.

Software simulation for the AM29000 risc processor is an example. Samples of the device are not expected until May, but potential users can take their C-language programs to AMD distributor Rapid Silicon to find out what sort of performance they can expect from the new device. Before being run on the software simulator, the C code in question is first optimized for use with the 29000 processor. Once optimized, the simulation software running under Unix on a Vax computer shows the designer what sort of performance to expect from the new processor.

Programming p.l.ds – correction

David Craggs points out that in Fig.6 of this article in the January issue, the references to other figures were one higher than they should have been, i.e., 'to Fig.4a' should have read 'to Fig.3a'. Also pin 19 of IC_8 must be taken low when data is to be passed through the LS245.

Multi-MAC for Astra

Chip-makers gear up for a satellite tv boom

RICHARD LAMBLEY

Plessey Semiconductors has received a considerable boost with the news that SES, the Luxembourg company behind the Astra 16-channel quasi-d.b.s. television satellite, has decided to allow programme providers to use DMAC transmission as an alternative to D2MAC. French and German cable tv operators favour D2MAC, a narrow-band standard designed to be compatible with their existing networks. But British interests prefer DMAC, the system chosen for the three British Satellite Broadcasting channels due to open next year. DMAC offers the same picture quality but twice the number of data packets, which means more capacity for teletext and wide-band digital sound channels.

With SES's decision, Plessey and its partners Philips and the design house Nordic VLSI will have the only chip set suitable for both new MAC services (and it decodes CMAC too): the rival ITT set handles only D2MAC. Plessey and Philips are now working against the clock so that receivers can be ready for the start of Astra's service. If decoders are not available in time, Astra may be obliged to open with PAL-encoded programmes.

The MAC consortium was set up last August, though chip designs were then already well advanced: Nordic VLSI was commissioned by the Norwegian PTT to begin work over three years ago, and Philips had spent four years on its own CMAC/D2MAC chips before the project was frozen in 1986.

Details of progress with the new chips were given by Peter Haywood of Plessey at a London seminar staged by SES, the first in a series aimed at promoting Astra to the television trade.

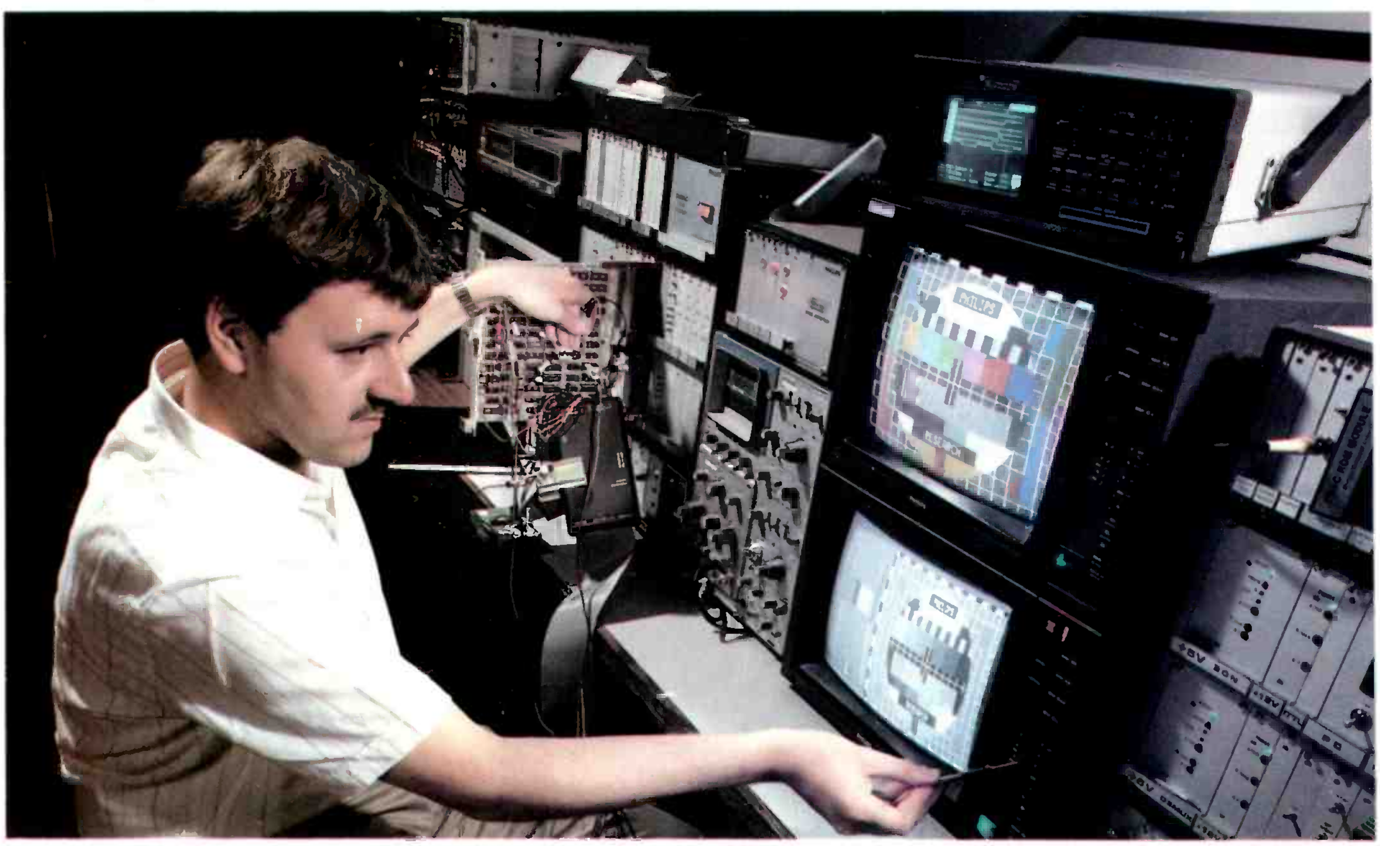
Largest in the set is the MV1710 video chip, designed in 1987 by Nordic and now produced by Plessey. Although this measured 10mm by 10mm, it worked first time,, said Haywood, and had been demonstrated with double-cut rotational picture scrambling (all-important to the pay-tv market). For Philips and Plessey, he added, it was the number one priority to have this chip ready in time.

The control chip MV1720 has been checked ready for processing and was due to be finished in April: expected at the same time is the MV1730 sound chip. Other chips on the sound side are types developed by Philips for Compact Disc players. Digital mixing will enable decoders to process stereo sound and commentary channels simultaneously. The d-rams are standard types and the a-to-d is a further standard item supplied by both Philips and Plessey. The only truly analogue device is the MAC-analogue chip, mothballed by Philips in 1986 and now being put into production again.

Because the decoder is software-controlled by the broadcaster, its most critical component is the microcontroller. This should be ready by late summer. Philips has a comprehensive set of application notes to enable set-makers to prototype their decoders using dummy microcontrollers, and is putting its Mitcham applications laboratories at the disposal of set manufacturers to enable them to get their products ready in the shortest possible time. It is likely to take 8-12 months for the chip set to reach production status. The consortium intends to dual-source the whole set and will make it available to all.

Plessey's MAC chips are being made in 1.5μm c-mos technology at the company's new Roborough plant (the one Prince Charles likened to a Victorian prison). However, the plant allows future reductions to 1.2, 1 and 0.8μm, each giving a 50% reduction in chip size and the promise of large-scale manufacture at the low costs required for full exploitation of the d.b.s. television market. The price target men-

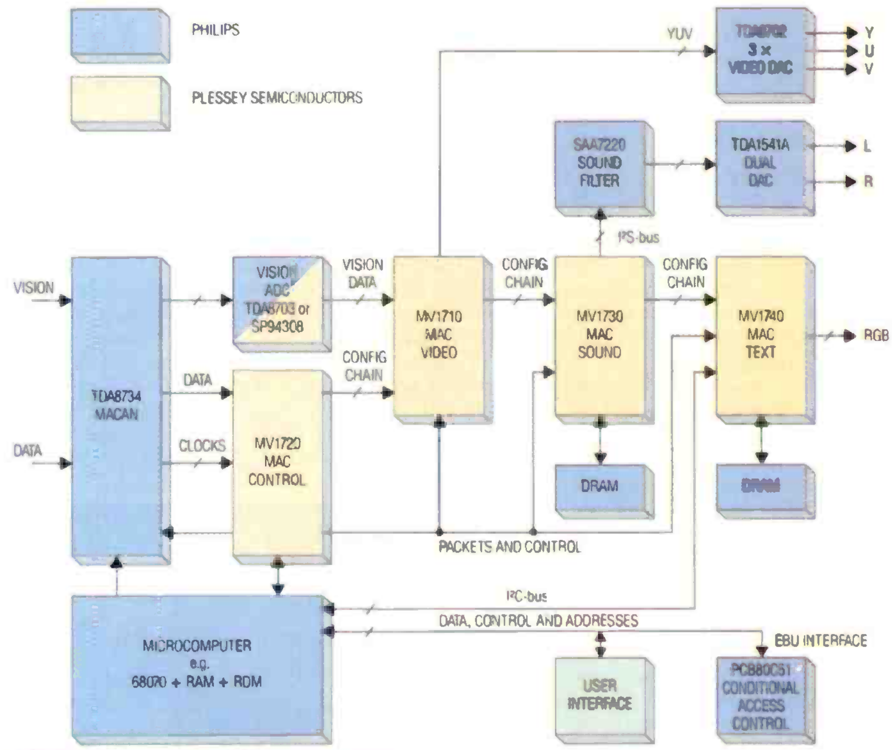
Work on the D2MAC standard continues at the Philips research laboratories at Eindhoven.



tioned by SES is £350-£450 for a system including receiver, 60cm dish and polarotor, though the company does not expect this to be reached with first-generation decoders.

Astra's launch on Ariane flight 27 has now slipped back to 1 November, 1988. Since positioning in orbit and commissioning will take 30-45 days, programme services will begin too late for the important pre-Christmas sales period. But since SES has no back-up satellite or launcher, any failure would mean that Astra will be overshadowed by the start of a service from BSB, whose satellite is due for launch in August 1989. A further European quasi-d.b.s. vehicle is promised by Eutelsat for 1990.

Uncertainty continues to obscure the make-up of Astra's programme package: British viewers are being encouraged to expect three English-language entertainment channels (one pay-tv, the others supported by advertising), plus five 'thematic' channels devoted to pop videos, sport or other forms of predominantly non-verbal communication, with further channels in French, German or Scandinavian languages. But at the time of writing, programme providers appear to be in no hurry to sign up. Asking price for a year's transponder rental is £5M.



Block diagram of the multi-standard MAC decoder incorporating ICs from Philips and Plessey Semiconductors.

F/X whoosh...

Anyone who has used sound effects in the radio studio or in other media will recognize that there is far more to obtaining realistic, believable noises-off than merely sending somebody out with a portable tape recorder.

Now a varied cross-section of the BBC's unrivalled effects collection is available to outside users in a set of ten Compact Discs. All but a few of the tracks have been recorded digitally in stereo or binaural stereo. Between them they should satisfy the vast majority of needs: there are one-off effects such as motor-cycles starting up and moving off or a power station being demolished as well as extended bands of background atmosphere lasting several minutes. Examples include exteriors such as a Welsh hillside with distant sheepdog, a school playground, a beach with seawash (and a choice of calm or choppy water), a rubbish crusher disposing of old tv sets; or interiors such as an art gallery, an Edinburgh pub on a busy Saturday night, the newsroom at *The Times*. Other discs in the set are devoted to wildlife sounds, transport by land, sea and air, household noises, human crowds in various settings, comedy and fantasy effects, and machinery.

The conditions of sale allow virtually unlimited use of the discs for commercial audio and video productions in perpetuity without any charge beyond the initial cost, which is £199 plus tax for the complete set. A leaflet which lists the contents in detail is available from BBC Enterprises in London on 01-576 0602.

NEW PRODUCTS

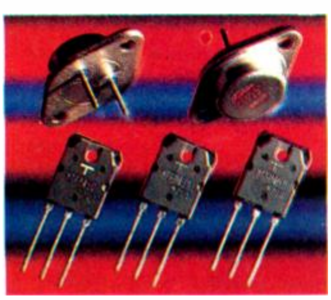
C runs on the transputer

The parallel processing power of Inmos transputers has been combined with the computer language C to produce a system that will be easy to understand by users of C while offering the phenomenal speed of a multi-transputer configuration.

Parallel C, developed by language compiler specialists, 3L, offers all the facilities of the standard Kernighan and Ritchie C compiler and adds the software tools required for parallel programming. As it compiles into transputer machine code, it bypasses the need to learn Occam or any other new language. Central to the operation is a 'configurer' which creates executable files from the independent tasks entered, distributing the tasks over the available processors. An application developed on a single processor will be automatically reallocated when run on a multi-transputer system to take full advantage of the higher performance available. In addition to a number of specific tasks running concurrently, the system can cope with individual tasks which may contain multiple parallel threads. Perhaps this combination of an industry-standard language with the undisputed power of the transputer will convert a number of new users to transputing. 3L Ltd, Peel House, Ladywell, Livingston EH54 6AG. Tel: 0506 5959.

Expanding mosfet range

There are a number of additions to the Toshiba mosfet range which now encompasses currents from 0.5A and 45A and voltages up to 1000V in a variety of packages. Toshiba are



second-sourcing the entire International Rectifier range.

Singled out, is a family of logic-level-compatible mosfets with a V_{gs} of 4V. Two other new mosfets are a 1000V/20A device with an on-resistance of 0.76Ω and a 500V/30A device with an on-state resistance of 0.18Ω. Both are designed for high-speed switching applications with high-efficiency and low losses. Toshiba (UK) Ltd, Semiconductor division, Centurian House, Watchmore Business Park, Blackwater Valley Road, Camberley, Surrey. Tel: 0276 694600.

Rugged oscilloscope is also safe

Field servicing is the main target for the OX709 dual-trace 30MHz oscilloscope which has a built in sealed lead-acid battery. This is automatically recharged when the instrument is connected to an external a.c. or d.c. supply. A large (120mm diagonal) c.r.t. screen is provided with a high-voltage beam to give a bright display, visible out of doors.

There is a variety of triggering options and a 'sensitivity' of 1mV/div.

Safety has been an important consideration with double insulation and strengthened, isolated terminals. It is claimed to be the first of its type that conforms to IEC and BS safety standards.

Applications include use in mobile laboratories, aerospace, at power stations and other high-voltage plants.

In keeping with its portability, the instrument is compact and weighs just 9.14kg. ITT Instruments, 346 Edinburgh Way, Slough, Berks SL1 4TU. Tel: 0753 824131.

Emitter-coupled 256K rams

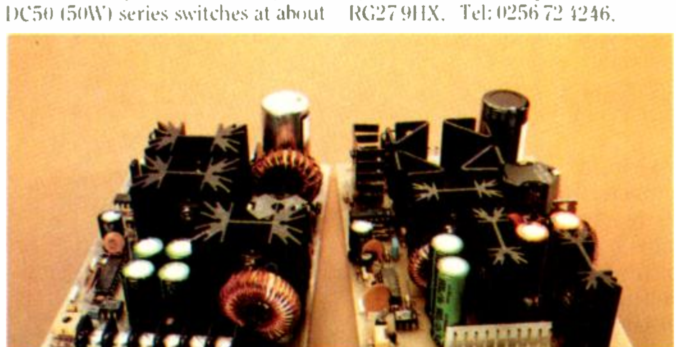
Super-fast 256Kbit rams are made by Hitachi in emitter-coupled logic (e.c.l.). The large memory capacity is coupled with low power consumption and an access time of 15ns with a minimum write pulse of 10ns.

The devices combine bipolar and c-mos devices in a 1μm process. Bipolar parts are used for the i/o circuitry and sense amplifiers with c-mos gates are used in the decoder. Each memory cell is a four-transistor n-mos device which also helps to speed the process. While they will be used to replace smaller e.c.l. memory devices, Hitachi also see them being used in place of d.rams and s.rams in the main memory of supercomputers and in file memory for test equipment. Previous e.c.l. devices did not have the capacity for these applications and also dissipated a lot of power. Hitachi Electronic Components (UK) Ltd, 21 Upton Road, Watford, Herts WD1 7TB. Tel: 0923 246488.

Power d.c. converters

Switching power supply d.c.-to-d.c. converters offer high power output and have an efficiency of up to 80%. Despite nominal inputs of 12V, 24V and 48V the converters will tolerate wide variations. Three outputs on each model are fully floating and can be used in combinations to produce 5V, 12V, 15V and 24V. Line and load regulation are typically 0.2% for the 50W version and 0.5% for 100W, while ripple and noise are typically less than 1%. All models can be shut down remotely when on standby. The DC50 (50W) series switches at about 100kHz and can be synchronized with an external clock to improve the signal:noise ratio. Input will be shut down if over or under-voltage limits are reached and the power limit protects against output short-circuits.

Applications are most likely to arise in telecommunications, battery-backed process control, in portable and mobile equipment, uninterruptible power supplies, and low-voltage rails. Gresham Powerdyne Ltd, Osborn Way, Hook, Hants RG27 9HX. Tel: 0256 72 4246.



Video measuring monitor

Both PAL and SECAM can be monitored on the multi-standard Grundig VE2010 Vectorscope. It is intended to monitor the outputs of colour tv cameras, video recorders and control rooms. It includes a waveform monitor and can measure the parameters peculiar to the system it is being used on, such as bell curves and frequencies with SECAM. Vector displays are used to view signal saturation at 75% and 100% levels. Synchronization of the colour picture carrier is provided internally or externally. Sync and picture inputs are both 75 Ω while the latter also has a transient filter. Instrumex Electronic Brokers, Dorcan House, Meadfield Road, Langley, Berks SL3 AL. Tel: 01 897 2434.

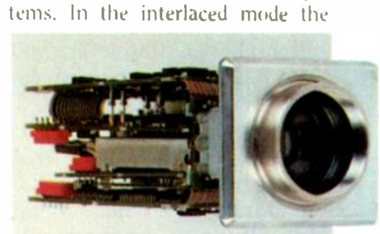
Add a lens to get a c.c.d. camera

A complete sub-assembly from Mullard requires only a lens and a chassis to provide a complete monochrome video camera for use in machine vision, surveillance and similar applications.

Central to the camera is a Philips solid-state image sensor which is accompanied by all the driving stages, pre-processing and power-supply circuits.

Two basic versions for 525 or 625-line systems are subdivided into three grades of sensor quality. The module offers a number of user-selectable options including interlace on or off, gamma on or off, automatic gain or not, automatic or manual iris control and internal or external sync.

The addition of the lens housing and choice of non-interlaced signals provides a system with 610 by 244 (EIA) or 604 by 294 (CCIR standard) pels. This can be used for machine vision or industrial inspection systems. In the interlaced mode the



camera can be connected directly to a monitor for security and surveillance systems when the screen offers 604 by 588 pels (CCIR standard).

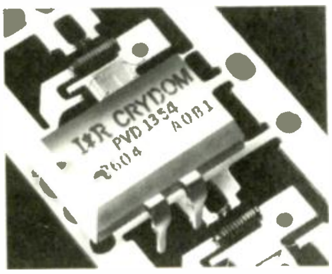
The sensor works in ambient light down to one lux, the condition at twilight, and can provide a usable image down to 0.5 lux. The output is a 1V peak-to-peak composite video signal. Standard commercial lenses may be fitted in the mount provided. Mullard Ltd (SSIS), Torrington Place, London WC1E 7HD. Tel: 01-580 6633.

NEW PRODUCTS

Miniature solid-state relay

Mosfet technology is used by International Rectifier to produce a solid-state relay that can switch up to 100V peak and can drive loads of up to 500mA.

PVD 13 can operate on control currents as low as 3mA with a switching time of less than 600μs. This makes it suitable for process control applications as well as multiplexing, telecommunications, and signal conditioning. Only four of the eight dil pins are used in the relay which is a single-pole normally open device. Input is opto-coupled to provide high input/output isolation and the mos-



fet output switch offers high off-state resistance. International Rectifier Co (GB) Ltd, Holland Road, Hurst Green, Oxted, Surrey RH8 9BB. Tel: 0883 713215.

$$G_2(t) = \frac{9}{128}\hbar^2\gamma^4\left\{\sin^4\beta g_0(t)+\frac{\cos^4\beta+6\cos^2\beta+1}{2}g_2(t)\right\} \qquad \pi\left[\frac{\tau_0}{t}\right]^{3/2}$$

$$\boxed{N_{xy} = -\frac{ab.D}{32}\;\frac{\sum_{m=1}^{\infty}\sum_{n=1}^{\infty} a_{mn}{}^2\left(\frac{m^2\pi^2}{a^2}+\frac{n^2\pi^2}{b^2}\right)^2}{\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} a_{mn}\,a_{ij}\,\frac{m\;n\;i\;j}{(m^2-i^2)\;(j^2-n^2)}}}$$

$$\begin{bmatrix} P_1 \\ P_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} . \begin{bmatrix} \Delta_1 \\ \Delta_2 \end{bmatrix} \qquad \underline{P} = \underline{K} . \underline{\Delta}$$

$$T = \frac{t}{2}\int_0^a\int_0^b\left[\sigma_x\left(\frac{\partial w}{\partial x}\right)^2+\sigma_y\left(\frac{\partial w}{\partial x}\right)^2+2\tau_{xy}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right]dx\,dy$$

Word processor for maths and science

The BBC Micro has always had a number of useful wordprocessor systems but a new, fourth, version of Ian Copestake's Wordpower is claimed to be easy to use and to provide screen images of exactly what will be printed. Screen formats are continually adjusted in accordance with the characters and control commands entered. Pop-up 'help' screens and menus guide the beginner through the use of the system. Continuous processing allows a file to be as long as the capacity of a disc, or even more than one disc.

Disc or rom versions of the wordprocessor are used with different models of the BBC and can also be used with a second processor. When used with the BBC Master, all characters entered appear on the screen, even foreign accents and mathematical symbols.

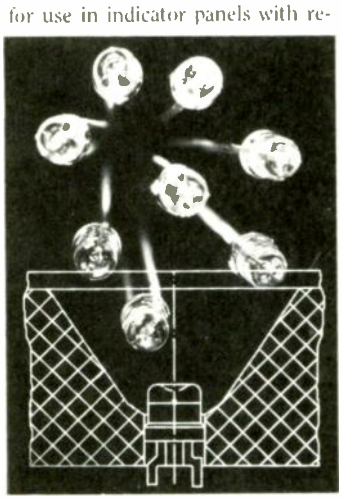
It is the typefaces and easy control sequences available that really makes the system a cut above rivals. It works in conjunction with Powerfont NTQ, a rom-based printer driver from Permanent Memory Systems. This can produce a number of different typefaces and allows the addition of many more, through disc images. One in particular is of use to engineers: Power Font M4 which provides Greek characters and multi-line mathematical symbols such as integral signs. Others provide the full set of accents for various foreign languages and different alphabets such as Cyrillic or Greek, with up to 14 languages on one disc.

When combined with an Epson-compatible printer, high-quality print can be obtained as can be seen from the sample printout.

A complete package consists of Wordpower, Powerfont NTQ and one extra font disc: all for £68 (+tax). Ian Copestake Software, 10 Frost Drive, Wirral, Merseyside L61 4XL. Tel: 051-648 6287.

Lighting areas with leds

Whole areas can be illuminated by newly designed leds from Siemens. This is achieved by surrounding the diodes with a conical reflector which transmits the light onto a diffuser and gives uniform light intensity across its area. The leds are intended for use in indicator panels with re-



flectors and diffusers shaped into figures, numbers or other symbols as may be used in instruments or on car dashboards. Red, green and yellow versions of the Argus leds can be made to a customer's specification. Siemens Ltd, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: 0932 785691.

Force-cooled heat sinks

If you have power components that need cooling fast, then these Marston Palmer fan-assisted heat sinks may be what you are looking for. One of them offers 'T' slots which allow many components to be securely fastened without drilling. Both have similar slots to fasten the sinks onto other equipment. The forced airflow gives the heatsinks very low thermal resistance. Marston Palmer Ltd, Wobaston Road, Fordhouses, Wolverhampton WV10 6QJ. Tel: 0902 397777.

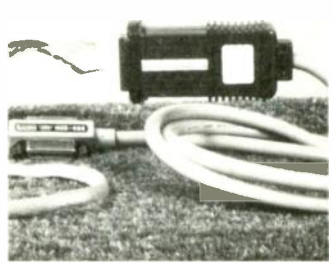
Fuses that stand fast

Bent legs provide an easy solution to mounting fuse holders on p.c.bs and Bussman has shown how. The 'kicked' terminals provide a spring which holds the fuseholder fast while being flow-soldered. As a result the soldered joint is more reliable. The fuse clips, with or without end stops, are made for the standard 6.3mm diameter fuses and can accommodate various lengths. They are made from tin-coated beryllium-copper and can carry up to 20A current. Bussman (UK), 1 Drumhead Road, Chorley, Lancs PR6 7BX. Tel: 02572 69533.

RS232 to GPIB converter

Just plug in a cable to a computer's RS232 port and it is transformed into a GBIP (IEE-488) controller. The secret is in the oversized connector shroud which conceals all the necessary electronics. No additional plug-in cards are required and the converter runs from the power on the RS232 signal lines.

GPIB-2001 offers full talk and listen facilities for a computer; GPIB-2002 is used with printers, plotters or any other listen-only device. One useful application is the ability to extend the operating distance of the IEEE-488 bus beyond its normal 20m range. Priced at £295, they are claimed to be one of the least expensive converters available. Roalan International, Britannic House, 28 St Peters Road, Bournemouth, Dorset BH1 2LP. Tel: 0202 296358.



Toroidal ferrites

Ring-shaped components have been added to the Iskra range of ferrite cores. Outside diameters range from 6mm to 42mm with 1mm steps between 12mm and 23mm; in all 20 different sizes. Five different grades of ferrite offer various permeability constants for different applications. For example in 6mm and 10mm sizes, 12G ferrite has a relative permeability of 10,000 which is particularly suitable for high-frequency chokes. Other applications include matching transformers, r.f. filters and low-power switch-mode power supplies where high-frequency switching leads to smaller smoothing capacitors. Iskra Ltd, Redlands, Coulsdon, Surrey CR3 2HT. Tel: 01-668 7141.

NEW PRODUCTS

Speed and power in an op-amp

With a quoted slew-rate of 1000V/μs and capable of handling outputs of up to ±35V and 750mA, the TP1465 op-amp can justly claim to be powerful and fast. This is partly achieved by the use of a fet input with a v.mos output. Other vital statistics are a 125dB open-loop gain and 2.5GHz gain bandwidth product. It operates from a ±15V to ±40V supply. Typical applications include accurate audio amplification, video distribution amplifers and yoke drivers, test equipment signal drivers, and for use with inductive or capacitive loads. Two versions offer standard or military specifications. The Teledyne Philbrick product is available through MCP Electronics Ltd, 26 Rosemont Road, Alperton, Wembley, Middlesex HA0 4QY. Tel: 01-902 1191.

Two-channel voltmeter

As well as offering two channels for comparative testing, the Trio/Kenwood VT-165 a.c. voltmeter gives an output so that a signal being measured can also be viewed on an oscilloscope.

The dual-pointer meter can take two inputs and compare them or both needles can be controlled from a single channel. Full-scale deflections

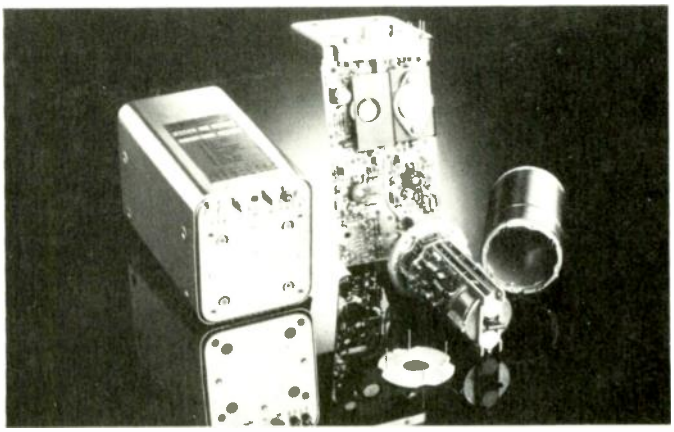
are from 300μV to 100V in 12 ranges with the frequency of inputs varying between 5Hz and 1MHz. Indirect attenuation switching by fet relays is claimed to offer high reliability and low signal: noise ratio. High isolation between the channels provide low crosstalk.

Wideband amplification is provided to the output with a voltage gain of about 70dB with 0.5V output at full-scale without a load. Output frequency response is 5Hz to 500kHz (−3dB) with an impedance of 600Ω with less than 1% distortion. Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs PR17 4BG. Tel: 0408 63570.

Highly stable crystal oscillators

Four particular areas have been chosen to demonstrate the superiority of a range of oven-controlled crystal oscillators. These are long and short term stability, phase noise and sensitivity to movement. Stability rating for the BVA oscillators are typically $1:10^{11}$/day long term and $5:10^{13}$/30s short-term. Phase noise at 1Hz is −12dBc and at 100Hz is −15dBc. Static 'g' sensitivity is $5:10^{10}$/g.

The devices are manufactured in Switzerland by Oscilloquartz, and are said to be suitable for both stand-alone applications and when used in conjunction with atomic frequency standards. Applications requiring such precision include time standard distribution, synchronization of satellite ground stations and the hierarchical exchange of data on a network. Chronos Technology Ltd, 377 Amersham Road, Hazlemere, High Wycombe, Bucks HP15 7HR. Tel: 0494 716146.



Software links Unix to the real world

Collaboration between Plessey and Ready Systems has produced an integrated real-time Unix system on the VMEbus. The particular advantage of the software is that it links existing, working kernels of the Unix with Ready's VRTX32, a real-time VMEbus operating system. The link is independent of specific processors and can therefore be used on a variety of systems.

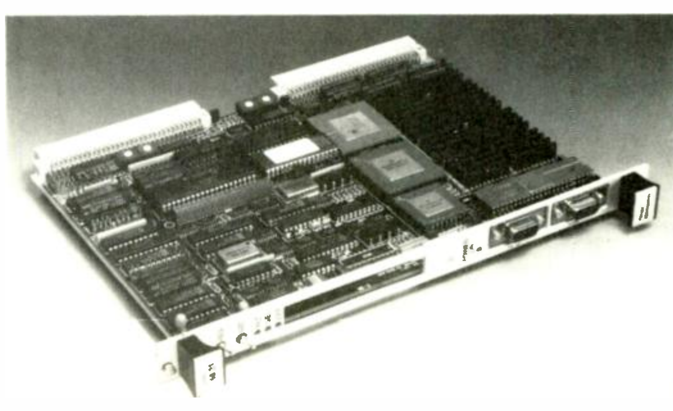
Multiprocessing is catered for in VXCEL, as it is called, which is built around the VXchip. This incorporates VRTX32 and includes a Unix channel for communication between Unix and VRTX. Also on VXchip are a number of housekeeping services such as memory management, i/o services, and system configuration with comprehensive debugging.

Built in to the real-time command system is a deterministic, i.e. mathematically predictable, response which gives a level of assured reliability. Software to drive external devices is written in C and applications vary from rom-based control cards in target systems through disc-based, file-oriented applications to multiprocessor, real-time/Unix applications.

Plessey VXCEL boards will run on VAX, Sun and similar development workstations, and can be used as target boards in such computers. Other hosts can access the boards through networks. Military applications are thought to be particularly important for such real-time systems and Ada programs can be developed through a package called RTAda which includes an Ada compiler and full program development aids.

The main advantage of VXCEL is that it is available now, and, as it is based on existing systems, is easier to use. Its independence from specific silicon devices gives it more universal appeal than systems produced by any particular processor manufacturer which will be specific to its processors.

Plessey Microsystems Ltd, Water Lane, Towcester, Northants NN12 7JN. Tel: 0327 50312.

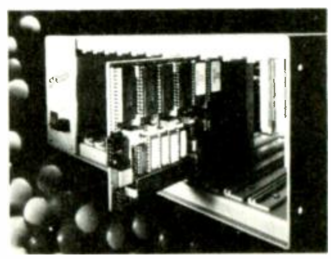


Low-cost heat sensor 'as good as platinum'

"As accurate as a platinum temperature probe at the cost of a resistor" is the claim made for PRC-100. It conforms to the DIN standard of 0.00385 Ω/Ω/°C, and a tracking chart comparing the device with a platinum probe is included in the specification sheet supplied with each sensor. Extra wires can be added to the two-wire devices if needed for extra lead-outs. Special-purpose versions with time constants or zero values to order. Kynmore Engineering Co. Ltd, 20 Kirby Street, London EC1N 8TS. Tel: 01-405 6060.

Low-cost STEbus computer

Entry into the world of computer buses has been made much less painful, financially and technically, by the introduction of the STEbox by British Telecom. It consists of a processor card, a five-slot backplane and a power supply. Two software packages are also included; a debug monitor and a terminal emulator which allows connection to a PC for system development.



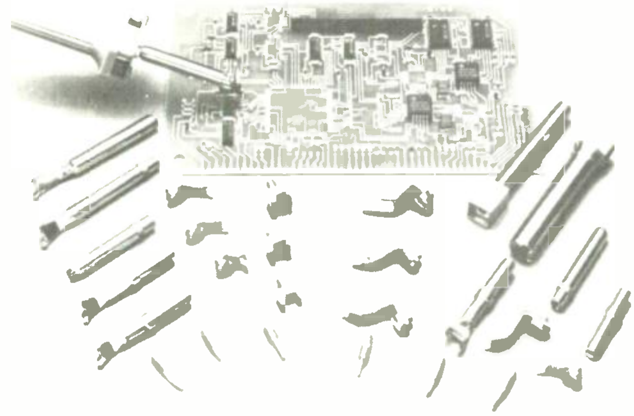
Four versions of the processor board are available, starting with the 8052 processor, which has the additional advantage of including a Basic interpreter in rom. This allows evaluation to begin by connecting a v.d.u. and the system, costing £360, is adequate to deal with a range of control functions. Top of the range, at £495, is a 16-bit 68000 processor system. STEbox was designed to provide a low-cost entry into STEbus development systems. BT's research found that the average system used three STE boards, so five was considered to be an optimum number. Space in the box can house up to five further cards if needed. The software provides communication and control mechanisms between the STEbox and a standard PC and allows code and control sequences to be developed on the PC and downloaded to the control computer. Code compilers can now be obtained very cheaply, so the cost is kept to a minimum in all respects. British Telecom Microprocessor Systems, Martlesham Heath, Ipswich IP5 7RE. Tel: 0473 645120.

NEW PRODUCTS

Mains interference simulator

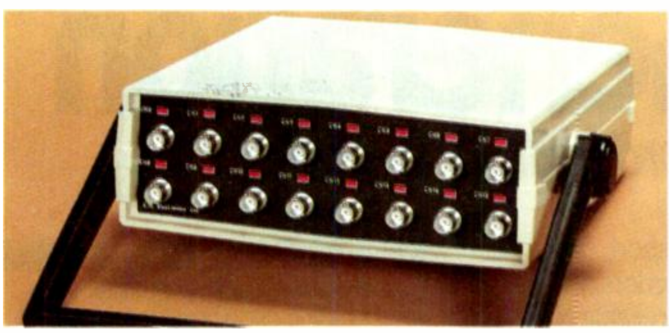
How can you tell how resistant your equipment is to mains interference? By using an interference simulator such as this one from Lyons Instruments. Conforming to a number of national and international standards, the BG1 interference simulator is claimed to offer repeatable, reliable tests by generating transient bursts of the type that may be encountered in an industrial environment. Transients generated are 50ns wide with 5ns rise time and in bursts 15ms long. Repetition rates and amplitudes are adjustable. Spark gaps are stabilized by thyristors to ensure repeatibility of the tests.

Output bursts can be applied directly to a.c. and d.c. supply lines with loads of up to 10A, or indirectly to data and control lines, using the couplers available. Lyons Instruments Ltd, Hoddeston, Herts. Tel: 0992 467161.



A-to-d converter with 16 channels

Low cost, high speed and high accuracy are claimed to be combined in a 16-channel analogue to digital converter from the CIL Group. PCI 1380 has a 16 bit, 20μs converter to provide 20,000 readings/s overall when stored in its own memory. With its own Z80 internal processor the instrument can communicate through GPIB and RS232 links and can transmit about 1000samples/s through the GPIB. RS232 data transfer speed depends on the data rate selected. Input signals can be accepted with a maximum of ±10V. CIL Group, 4 Wayside, Commerce Way, Lancing, West Sussex BN15 8TA. Tel: 0903 765225.



Photosensors for hostile environment

Hazardous environments offer no problems to Elesta photosensors, says Radiatron, as they are proofed to the international standard, IP67. They can be mounted through a panel or bolted to a flat surface. Three models cover distances up to 7m, between zero and three metres, and up to 200mm. All offer sensitivity adjustment, and have built-in amplifiers, indicator leds and light or dark switching. Flush faces reduce interference from dust and all models operate over a temperature range of −20°C to +90°C. Radiatron Components Ltd, Crown Road, Twickenham, Middlesex TW1 3ET.

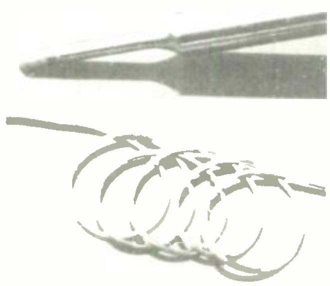
Tel: 01 891 1221.

Surface mounting by hand

Three products have come to our attention, all associated with prototyping surface mounted components.

First comes an experimental soldering kit with a variety of tip shapes and sizes to fit most surface mount components. Hand soldering and desoldering for reworking s.m.d. circuit boards can be carried out, including field service repair work. Two different soldering irons may be used with the bits. One, SMD11 10 from Hexacon, who make the kit is particularly suited to close work under a microscope. Adaptors are included to allow the tips to be used with other irons or workstations. Intertronics, Unit 9, Station Field Industrial Estate, Banbury Road, Kidlington, Oxon OX5 1ID. Tel: 0865 842842.

Fine solder. To go with the closer pitches and smaller pads of surface mounted components it is necessary to use finer solder wire. One such is made by United Alloys who offer a 0.5mm diameter resin cored wire on 250g reels. An unusual combination



of 63% tin to 37% lead is used, which conforms to grade AP of BS219 and is claimed to increase the flow and eliminate the 'pasty' behaviour of solders between 183°C and 188°C. The wire has a melting point of 183°C, and uses a resin flux with little residue and a minimum of fumes. Available through Zeltex (UK) Ltd, Crosslands Lane, North Cave, Brough, North Humberside HU15 PG. Tel: 04302 3859.

Prototyping with wire wrap. Another solution to prototyping is offered by the Microwrap system from C.E. Automation. This provides wire wrapping on posts of the same pitch as surface mounted components. Thus prototype boards can be produced with the same component density as production p.c.bs. 34 gauge insulated wire can be wrapped onto 0.012in (0.305mm) square phosphor bronze terminals on 0.05in (1.27mm) pitch. Terminals are provided with tracks to pads for the components which can be soldered or socketed. Dual in line devices are usually socketed to allow wires to be routed beneath the device. Boards wrapped with Kapton insulated wire can be flow soldered in conventional wave machines. C.E. Automation also offer extensive design facilities and have the cad equipment to turn a Microwrapped board into a plotted pattern for a production board.

C.E. Automation Ltd, Unit 17, Suttons Industrial Park, London Road, Earley, Reading, Berks RG6 1AZ. Tel: 0734 669414.

High-speed buffer

Buffers are required for current matching, impedance matching and to increase the fan out of logic components. One from VTC Inc. offers high speed and unity gain. Speed is evident from the quoted slew rate of 700V/ms and the rise time of 3ns. Output current is up to ±100mA so the device is suitable for line drivers, video impedance transformation, op amp isolation and input buffering the d to a converters and comparators.

VA003 runs on a ±5V supply and consumes 1.15W. Five options of packaging are available: surface mouth or conventional dil in plastic or ceramic with an 8 pin, TO 99 metal can version. Industrial or Mil. Spec. versions can also be specified. Impulse Electronics, Hammond House, Caterham, Surrey CR3 6XG. Tel: 0883 46433.

TELEVISION BROADCAST

Constant luminance at last?

The European HD-MAC compatible high-definition television satellite transmission standard to be proposed by the Eureka EU-95 team may be the first colour system to use the true constant-luminance principle on which all compatible colour-encoding systems have been based but which has never before been implemented in a colour-encoding standard.

When the NTSC standard was developed in the early 1950s, it was usually explained as though luminance and chrominance information was transmitted without error; but in practice, largely to simplify the receiver decoders, this was not the case. An ideal system would transmit a gamma-corrected luminance (Y) signal identical with a black-and-white-only transmission.

In practice, the luminance signal of NTSC was composed of gamma-corrected R, G, B primary signals. This means that saturated colours have inadequate luminance components, and this can be detected on black-and-white receivers. Some of the luminance information is transmitted in the severely bandwidth-limited chrominance channels.

Although, with colour receivers, it might be supposed that the missing luminance component would be recovered in the decoder matrix, the limited bandwidth of the I and Q channels means that medium and fine detail luminance information is lost in transmission. The effects are visible on heavily saturated blues and reds, although of little practical significance on colours of medium or low saturation.

During the protracted controversy in the mid-1960s on the choice of a colour-encoding system for Europe, Ivan James, then chief camera designer at EMI, argued strongly for true constant luminance: but in the outcome this was not adopted for either PAL or SECAM, although a number of experiments were undertaken on behalf of the ITV companies by ABC at Teddington. More recently, in retirement Ivan James has continued his advocacy of true constant luminance, urging, without success, that the IBA should adopt it for the MAC satellite transmission standard with its time-multiplexed component format.

At an IEE lecture "Advances in TV studio origination standards" given jointly by Dr Chris Dalton (Thames Television) and Paul Wilcock (Granada) it was revealed, to the evident surprise of most of the audience, that HD-MAC (1250/50/2:1) is being designed to use true constant luminance, primarily to take advantage of the improvement in signal-to-noise ratios possible with component signals. This has followed a new comparison of conventional and constant-luminance encoding.

In the subsequent discussion several speakers queried whether departing from the usual matrix resulted in any practical benefit for viewers. Paul Wilcock insisted that it does provide improvement not just in the quality of the signal but also in the transmission channel. The slight degree of incompatibility with MAC and conventiona decoding matrices should not seriously degrade pictures.

Mike Cox recalled that in the 1960s tests at Teddington, constant luminance had been found sensitive to camera registration errors, which showed up as colour fringes. Dr Dalton agreed this was "absolutely right" but felt that with modern technology camera registration, particularly at the edges, can be held much better than in the 1960s and so this problem should not exist today.

Brian Scott (Thames Television) wondered whether the UK should not be following the USA in turning attention more towards developing improved definition systems that could be transmitted on terrestrial networks, with no likely requirement on the part of either BBC or ITV to transmit through satellites. He accepted that there would be technical advantages in originating programme material with 1250 lines and then converting down, but felt that this would be an expensive way of improving picture quality.

Earlier, Paul Wilcock had noted the use of S-MAC (studio MAC) at the Liverpool studios of Granada and also the development of the ACLE (analogue component link equipment) standard to permit component video signals to be transmitted through bandwidth-limited microwave links for electronic news gathering etc.

Flat antennas for d.b.s. reception

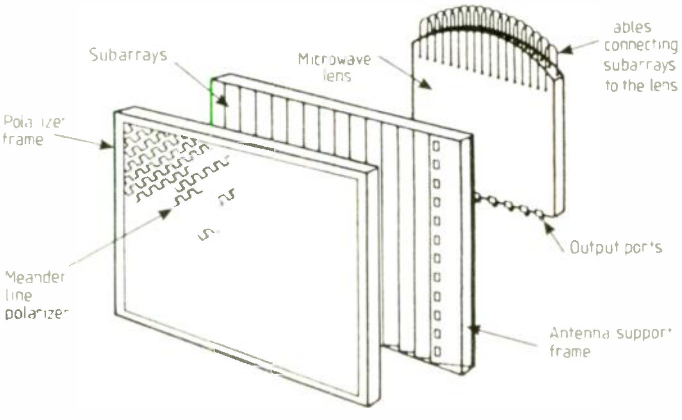
The considerable practical advantages that would be offered by flat antenna arrays rather than the usual parabolic reflector antennas for d.b.s. reception have long been recognized and various designs demonstrated. A flat antenna mounted directly on the side of a house would be less obtrusive and hence environmentally more acceptable, and better able to withstand high winds. The disadvantages are rather less gain than from an equivalently-sized parabolic dish and the requirement for effective, low-cost beam-steering, since in very few houses is it likely that a wall facing precisely in the right direction would be available.

While several designs have shown that suitable flat arrays of printed dipole elements can be implemented without undue difficulty, effective beam-steering, with its complexity, particularly when this involves active devices, has remained a formidable obstacle.

M.C.D. Maddocks (BBC Research) has recently described in *Electronics Letters* (4 February, 1988, pages 173-4) a polar method of beam steering, with the beam slewed in one plane and mechanically rotated in its own plane to achieve the second degree of freedom (UK patent application no 8711270). His design is based on a number of linear arrays using a Rotman microwave lens, with triplate construction, as a beam-forming network, suitable for mounting flat on any south-west facing wall (±45°). A full sized array would have an aperture of about 0.6m² but a reduced-size experimental antenna (0.3m²) has been constructed and its performance measured to demonstrate the feasibility of this approach, using low-cost materials (principally copper-clad polyimide film and microwave foam). This has a boresight gain of 28dBi and crosspolar discrimination better than 20dB. It produces seven slewed beams over the range of angles 0° to 54° on one side of broadside. It is claimed that a full-size array should achieve both a higher gain and narrower beam spacings and would be satisfactory for d.b.s. reception throughout the UK and in many other countries where the full WARC-specified 30dB of cross-polar discrimination for receiving antennas is unlikely to be necessary.

Television Broadcast is written by Pat Hawker.

Exploded view of a steerable flat-plate d.b.s. antenna.



British Electronics Week

'The Week' has come round again and this year is even bigger. It is probably impossible for even the most dedicated enthusiast to visit every single stand at The Week within the three days that it is open. However if the visitor decides to choose specific shows to concentrate on, the idea of such a gigantic show becomes more manageable. It is best to consider it as seven independent exhibitions which happen to occur at the same time, under one roof.

All-Electronics/ECIF Show. This is the parent exhibition to which all the others have been added over the years. It is a general electronics exhibition with some emphasis on components. It is the largest of the seven exhibitions occupying the main hall and gallery of Olympia 2, with over 200 stands.

Automatic Test Equipment was an established annual show before it became incorporated into 'The Week', last year. Of note is the change in emphasis from isolated areas of automation to integrated networked a.t.e. facilities with central computer control and recording of test results. Many IEEE488-controlled instruments are on show.

Circuit Technology concentrates on printed-circuit board design and manufacture. It includes c.a.d. systems as well as soldering equipment and machinery. Large, working, production-line machinery will be displayed by many exhibitors.

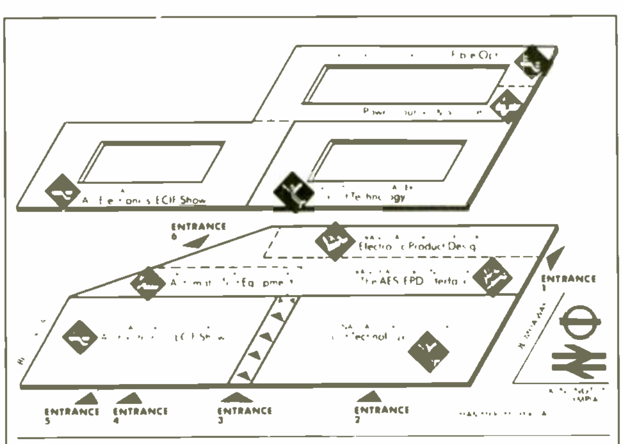
Electronic Product Design. International semiconductor companies use this show as a forum for meeting designers and discussing the merits and applications of their products. Other companies use this area of the Grand Hall for the large prestige display stands.

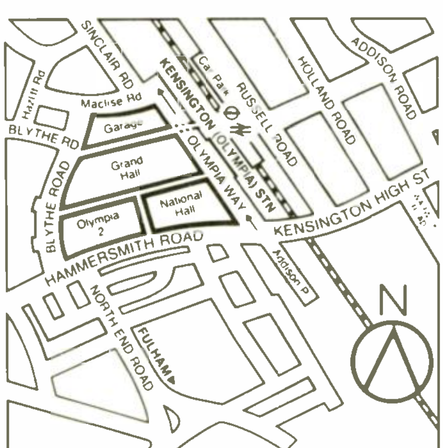
Fibre Optics is claimed to be the only dedicated exhibition for this technology, in the UK. Over 100 stands are devoted to optical communications in the gallery of the Grand Hall.

Power Sources and Supplies was launched at the Week last year. This year on the Gallery of the Grand Hall, 75 stands offer a shop window on power supplies batteries, photovoltaic cells and power back-up systems.

The Interface is located in the Grand Hall and is devoted to those companies who feel that they can contribute equally to the component-oriented All-Electronics Show and the Electronic Product Design show. For this reason, it is placed strategically between the two exhibitions. Over two hundred exhibitors have selected this new addition to 'The Week' to display ranges of products that they hope will appeal to designers of products and systems.

THE BRITISH ELECTRONICS WEEK. OLYMPIA, LONDON. 26-28 APRIL 1988.





How to get there

Olympia has its own Underground station (Kensington Olympia) and there is a frequent shuttle service between it and Earl's Court station on the main Underground network. Many buses stop outside the halls on Hammersmith Road.

Admission is £5 at the door but free tickets are available from the companies exhibiting and from the organizers. Entrance includes a massive catalogue. Organized by Evan Steadman Services Ltd, The Hub, Emerson Close, Saffron Walden, Essex CB10 1HL.

Circuit Technology

New from Marconi Instruments is the 2383 spectrum analyser which covers 100Hz to 4.2GHz. It is intended to fill the 'microwave gap' between older 1GHz instruments and those covering up to 20GHz, the latter being very expensive and less precise for critical second and third-harmonic components in many modern communications systems. These include radio pagers, cellular radios and space communications. Resolution of 3Hz will be of interest to designers of low-noise oscillators for use in radio.

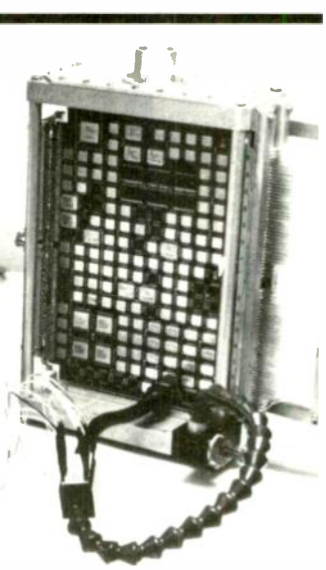
Also built in to the instrument is a tracking generator for use in the testing of components such as s.a.w. and all other types of r.f. filter. Marconi Instruments Ltd, Longacres, St. Albans, Herts AL4 0JN. Tel: 0727 59292. (Stand J835).

Automatic Test Equipment

Surface-mounted components can be monitored in circuit with the use of the SMOCC (signal measurement on chip carriers). This Swedish product will receive its first British showing at the ATE section of 'The Week', on the Antron stand, C243F. Each probe is held in position by a vacuum sucker, with precision test pins making contact with the pads of the devices under test. Oscilloscopes, logic analysers or other test equipment are used with the probes. Different sizes of the probe are available for common sizes of chip carriers and flat-pack components. Precision machining of the probes and contact pins ensure accurate contact pin positioning. Antron Electronics Ltd, 39 Kings Road, Haslemere, Surrey GU27 2QA.
Tel: 0428 54541.

Electronics Product Design

In the Electronics Product Design Section of 'the Week' is Instrumex, who is displaying a portable f.f.t. analyser from Hakuto. This instrument covers a frequency range from d.c. to 20kHz and the internal a-to-d converter has 12-bit resolution. Received data is displayed as a spectrum or histogram with cursor measurement for up to 11 harmonics. Up to 40 displays can be stored internally. Mathematical calculation is provided to give calculations of total harmonic distortion, harmonic power and to perform integration and differentiation on the spectrum displays. Another advantage of the instrument is its low cost of £2821. Instrumex, Dorcan House, Meadfield Road, Langley, Berks SL3 8AL. Tel: 01-897 2434. (Stand E424A).



All-Electronics Show

A dual-channel programmable pulse generator is to be shown for the first time at the All-Electronics Show. (Global Specialities, Stand B103). The instrument offers single and double pulses with delays, and a number of burst cycles. Outputs offer the separated components of the pulses directly or through t.t.l. and e.c.l.-compatible connections. The instrument is programmable through the front panel and through the GPIB connector by a master control computer.

The company is also launching an educational package which offers hardware and a comprehensive manual on automotive electronics.

The whole Global range of test instruments has received a face-lift in time for the show. Global Specialities, Shire Hill Ind. Estate, Saffron Walden, Essex CB11 3AQ. Tel: 0799 21682.

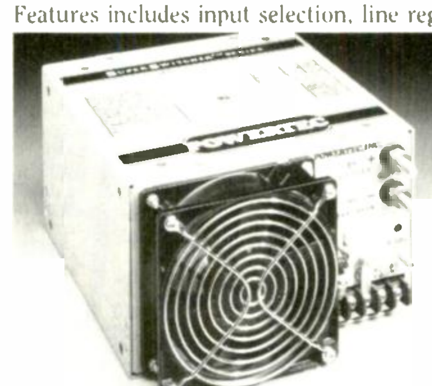
The Interface

Thurlby Electronics have chosen this new part of the show to display its wares, amongst which is an adaptor which adds digital storage facilities to any analogue oscilloscope. The performance of the combined instrument is claimed to be comparable with d.s.os costing much more. DSA 524 provides a sampling rate of 20Msamples/s and 4K-words of digitizing memory.

Thurlby are the exclusive UK agents for Kenwood Instruments and another new product featured at the show will be a 40MHz analogue oscilloscope that uses an internal analogue sampling technique to extend the bandwidth to 100MHz. Thurlby Electronics Ltd, New Road, St. Ives, Huntingdon, Cambs PE17 4BG. Tel: 0480 63570. (Stand D281).

Power Sources and Supplies

New to the Bonar Advance product range is the series 9 range of up to 1800W single-output SuperSwitcher power supplies with ratings of 2V and 200A up to 48V with 43A. They are designed to meet safety and emission standards of international authorities. Features includes input selection, line reg-



ulation to within 5mV or 0.1%, overvoltage protection, and fault-tolerant redundancy protection. A number of other new power supplies will be on show for the first time in the UK. Bonar Advance Ltd, Raynham Road, Bishop's Stortford, Herts CM23 5PF. Tel: 0279 55155. (Stand B91).

Radio Communications

E.m.c. hurdles raised by 1990

The IERE's London colloquium on the "European Community EMC Directive" attracted a house-full audience of some 270 delegates. It is planned to repeat this DTI-inspired teach-in on May 26. It was however noticeable that most of the delegates were concerned with the use rather than the abuse of the radio spectrum, although the e.m.c. directive, if implemented and enforced in its present draft form, will impact strongly on virtually all manufacturers of electrical and electronic products.

With the exception of motor vehicles and tractors, the directive is intended to apply to any apparatus liable to cause an "electromagnetic disturbance" anywhere in the e.m. spectrum, or the performance of which is liable to be affected by such disturbances. Member states will be committed to taking "all necessary measures" to ensure that all apparatus placed on the market or taken into service does not generate electromagnetic disturbance exceeding "a level allowing radio and telecommunications equipment and other apparatus to operate as intended and has "an adequate level of intrinsic immunity to electromagnetic disturbance".

Dr Keith Shotton (Director of Radio Technology, DTI) pointed out that the EC has brought forward its e.m.c. proposals in preparation for the single European market due to become effective in 1992. This will bring full freedom of movement of goods, services and persons, sweeping away European barriers and providing a market of 320 million people. "We should welcome the EC e.m.c. directive but there are areas of concern", he said.

Dr Alan Whitehouse (DTI) outlined the far-reaching scope of the draft directive which is due to be submitted to the European Council of Ministers in June this year and is provisionally due to be implemented on 1 January, 1990. It covers not only electromagnetic interference to and from radio and telecommunications equipment but also information technology equipment, industrial, scientific, and medical equipment – in fact all equipment, but particularly that incorporating microprocessors. It also requires that "equipment should not malfunction in whatever hostile electromagnetic environment it may reasonably be expected to operate".

Article 7.3 allows a manufacturer (except for some telecommunications equipment requiring type-approval) to certify conformity with the objectives where either a relevant standard does not exist or where he chooses not to use the existing relevant standard. But in this case the manufacturer has to keep a 'technical file' at the disposal of the national administration and containing the procedures used to ensure conformity.

In the event of non-conformity, Article 9 requires an administration to take all appropriate measures to withdraw the apparatus from the market, prohibit its being placed on the market and restricting its free movement.

On paper, these are indeed draconian measures that could remove from the market a vast number of present products. But can they or will they be enforced? In a concluding paper, John Ketchell (DTI Radio Investigation Service) outlined the likely effect of the EC directive on UK e.m.c. regulations and their enforcement. He showed that existing primary legislation will require extensive changes and that a whole new range of secondary legislation will be needed, following consultation with industry. But he also stressed that it is unlikely that RIS will be given more resources, except the additional measurement equipment needed to test to new statutory limits: "Enforcement will thus remain largely complaint-driven although the likely easing of other pressures should provide the resources for more complaints about non-compliant appliances to be handled".

Speakers from ERA Technology, British Telecom, ICL and Plessey Assessment Services as well as the DTI explained what is being done to revise existing BSI and other relevant standards, the e.m.c. aspects of information technology equipment and radio systems, and the future role of independent e.m.c. test houses.

During the discussion period, it was noted that many appliances and products are being designed now for marketing in 1990 and that many firms not directly concerned with the use of the radio spectrum still have little knowledge or appreciation of e.m.c. problems and the difficulties they may encounter in meeting standards and regulations that will result from the EC directive. As one delegate put it: "Can anything more be done to spread the word that they ought to be interested? Some manufacturers will do nothing and will get away with it. The directive requires us to restrict placing non-compliant products on the market – yet enforcement will remain complaint-driven. Germany may enforce regulations strictly while the UK could become a dumping ground for non-compliant goods".

Breaking the code

It has long been evident that the most prolific and reliable source of high-grade intelligence during the Second World War, both for the Allies and for the Axis powers, was derived from signals intelligence (sigint): the interception, traffic analysis and decryption of enemy Service, security and diplomatic traffic.

The final volume (vol.3, Part II) of Professor F.H. Hinsley's mammoth 3000-page-plus "British Intelligence in the Second World War – its influence on strategy and operation" underlines once more the vital importance of the Bletchley Park operations and the SCU/SLU network of special h.f. communications links that passed the Ultra material to the army and air force. But the restrictions imposed on him, in being required to preserve secrecy about intelligence techniques and the individuals who made up the oddly-assorted wartime intelligence community, make the volumes far less illuminating than M.R.D. Foot's "SOE in France" official history published some 25 years ago. It is surely pointless to carefully refrain from naming even "C" (head of the Special Intelligence Service) as Sir Stewart Menzies when hundreds of earlier, if less official, books have identified virtually all senior figures in SIS, GC&CS, SCU and the Y services.

However, Professor Hinsley has taken the opportunity in the final volume of reassessing the Polish, French and British contributions to the breaking of the Enigma machine cipher, including the important part played by the French – by their spy in the German cipher bureau, Hans-Thilo Schmidt.

But he assumes that the Germans never discovered that the British were reading their messages. This is surely only partly true. There is a convincing story that Schmidt was finally arrested in 1942 and committed suicide in his cell. This was the result of the capture by the Germans in 1940 of a freight train filled with documents from the French ministries, some of which (much later) were identified as stemming from the French Special Services. These included a list of payments made to their agents in Germany. It was realized, from the large payments, that Schmidt had supplied the French full details of their cryptographic and radio systems, including the machines, tables of call signs, details of the German intercept services etc. The Germans realised that this information may have been shared with the British, but apparently did not discover that it had (much earlier) been passed to the Poles.

Hinsley underlines that it is not enough to gather reliable intelligence unless you can persuade the fighting services to use it properly. Montgomery's HQ was warned by the Dutch resistance that German elite forces were stationed in Arnhem and this was confirmed by sigint, yet Market Garden was allowed to go ahead regardless.

Hinsley also shows that the 1944 Ardennes offensive caught the Allies completely unprepared, partly because the Germans had imposed radio silence. What he does not say, and perhaps it never got into the records, was that SIS were preparing to put agents into precisely the area where the German forces were assembling when they were forbidden to do so by the Americans, who regarded the area as their responsibility yet failed to detect the build-up.

Radio Communications is written by Pat Hawker.

RADIO BROADCAST

FMX taking off in USA?

In 1985, the CBS Technology Center in collaboration with the US National Association of Broadcasters (NAB) developed and field-tested an extended-range compatible stereo broadcast system ("FMX"), claimed to overcome the problem of stereo hiss in the large part of the service area between the 60dB (µV) limit for good stereo reception and the 48dB limit for mono. One of the co-inventors, Emil Torrick, believes that FMX is the first major improvement to stereo radio since the standardization of the pilot-tone system in 1961. European broadcasters have been lukewarm, expressing concern about the effect of FMX on existing receivers in pronounced multipath conditions.

FMX is a linked compression and expansion system, implemented by providing a heavily compressed second (S') stereo difference signal at 38kHz in accurate phase-quadrature with the normal stereo difference (S) signal, which is then used as a decoding reference envelope to expand the compressed, hiss-reduced, S' signal. At the transmitter a re-entrant compressor reduces the compression ratio at high audio levels to prevent over-modulation resulting from summation of the two 38kHz signals.

In June 1987 at the Chicago consumer electronics conference, Sanyo Electric described a one-chip (30 pin) decoder for FMX. This includes automatic switching from stereo to mono when significant multipath is detected in a moving vehicle. At the January 1988 winter Consumer Electronics Show (Las Vegas), ten Japanese manufacturers showed prototype FMX-equipped stereo receivers and seem confident that up to 100 American broadcasters will be radiating FMX-encoded signals by the end of the year.

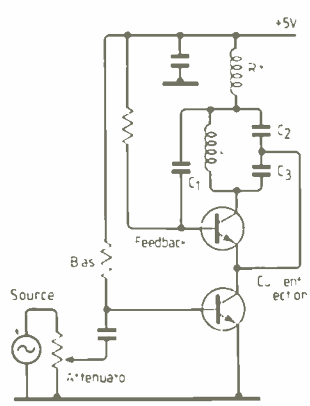
With the proposed phasing-out of "simulcasting" by broadcasters in the UK, the possibility of suppressing stereo hiss by some 20dB in a large part of their service areas would be very attractive. But broadcasters still need to be convinced that cross-talk between the S and S' signals, due to phase changes when echo signals destroy the phase quadrature, would not seriously degrade reception on receivers not equipped with an FMX decoder. Nevertheless the potential improvement in stereo service areas certainly means that FMX deserves detailed evaluation.

Injection-synchronized oscillators

In 1947, Professor D.G. Tucker introduced a novel form of homodyne broadcast receiver, which he christened a synchrodyne receiver. It featured coherent detection of a.m. signals by means of an oscillator forced into synchronous oscillation by injecting some of the incoming carrier and then using this to demodulate the signal directly to audio by means of a double-balanced ring modulator, with inter-station tuning whistles suppressed.

The linearity of the homodyne configuration means that selectivity characteristics can be determined at audio frequency, while the principle can be extended to permit separation of signals whose sidebands overlap, i.e. by single- or selectable-sideband demodulation.

Although the Tucker synchrodyne attracted considerable interest it failed to make an impact upon domestic broadcast receiver design, although homodyne principles were subsequently used by Costas in a 1956 high-performance communications receiver intended to demonstrate the advantages of double-sideband suppressed-carrier systems over s.s.b. Subsequently, the homodyne direct conversion principle has been widely used by short-wave listeners and radio amateurs for c.w./s.s.b. reception where the oscillator does not require to be phase-synchronous and can be free-running.



A few experimental homodyne broadcast designs have appeared (e.g. J.W. Herbert, *Wireless World*, September 1973) using phase-locked-loop i.c. devices, or phase locking to an internal crystal reference oscillator to provide 9kHz incremental steps (Macario, Crane & Walters, *EBU Review – Technical*, no 145, June 1974). But the use of direct injection to synchronize an oscillator appears to have made little progress.

However, Vasil Uzunoglu and M.H.White have described and patented what they claim to be an improved form of synchronous oscillator "substantially different from the Van der Pol and injection-locked oscillators covered in the literature" (though the principle appears virtually the same). This has been described primarily for carrier and clock-recovery applications but would appear to be equally suitable for synchrodyne-type broadcast receivers. As a tracking oscillator with a narrow-resolution bandwidth, the synchronous oscillator is claimed to track input signals down to −45dB s.n.r. at strengths down to −100dBm, acquiring input frequency within a few cycles, with phase following significantly quicker than with p.l.l. techniques (Uzunoglu and White *IEEE J. Solid-State Circuits*, December 1985, pp1214-6, US patents 4,355,404 4,274,067 4,356,456).

In the absence of an external signal the synchronous oscillator is a simple free-running oscillator. When a signal is applied the synchronous oscillator immediately begins to track and lock to it. The output from the oscillator is independent of the external signal level. It constitutes a multifunctional network: (a) a bandpass filter for r.f. and frequency-modulated signals and as an a.m. to p.m. converter of a.m. signals; (b) a synchronization and tracking network; and (c) a frequency divider. Its use for carrier and clock recovery in a high-speed modem operating in a burst mode has been described, but a number of other possibilities exist. Additional filtering networks can be incorporated within the basic configuration.

If shown to be applicable to a synchrodyne broadcast receiver for m.f. or h.f., it should be capable of achieving excellent, readily-variable selectivity based on the near-unity shape factors possible with a.f. low-pass filters. Such receivers would also be suitable for receiving reduced-carrier s.s.b. broadcasting while the exalted-carrier should reduce selective-fading distortion on conventional a.m. signals.

Institute of Broadcast Sound

The Institute of Broadcast Sound, set up in 1977, draws support from members in some 60 companies including sound engineers, sound supervisors and managers from radio, television, outside broadcasts and film. Now it has launched its own journal *Line Up* in association with BSO Publications Ltd. The first issue, dated February 1988, runs to 50 pages, under the editorship of Richard Lamont. It includes a controversial commentary by Norman McLeod in which he questions the money being spent by the BBC in promoting f.m. radio and in particular the cost of the new Radio Data System (RDS), claiming: "The development expenditure of this inaudible and as yet invisible phenomenon appears to account for more than one per cent of the BBC's annual budget for sound broadcasting. A whole secretariat seems to have been appointed to push this concept not only within the UK but across the civilised world as we know it. Why?" He concludes his provocative article by writing: "What would really attract people to v.h.f. listening would be to put attractive, new, different, thoroughly analogue *programmes* for people to listen to, but there seems little prospect of this approach being awarded its own secretariat by the BBC."

Radio Broadcast is written by Pat Hawker.

Memory shortage affects computers

Poor yield in megabit memory chips has caused a crisis in the computer industry, says Jim Beveridge of Dataquest. A projected price of $17 has increased to $40 because of the world shortage of the parts, though it is possible to order six months ahead for $25 parts. One reason for the poor yield has been the adoption of new technologies such as the trench capacitors adopted by Texas Instruments, which have not worked as well as planned, and the trend towards further miniaturization. By contrast, Toshiba has a much higher yield in its megabit d.rams and has a working production line. The Toshiba technology is also being used by Motorola and Siemens. Toshiba reckon they can make 200 million parts in a year, which even at the original quoted price of $17 and the actual manufacturing cost of about $7 will lead to massive (c. $750M) profits.

The shortage of the 1Mbit parts has led to computer manufacturers reviving their 256Kbit-based memory boards. Unfortunately this has placed a sudden demand on the silicon manufacturers who can't keep up with it, so the price of these parts shot up.

Such shortages also lead to a bias in distribution. American and Japanese parts are most likely to go first to US and Far East customers, starving the European market and possibly leading some local manufacturers into considerable difficulty. For example, although IBM make some of its own memory devices, it also buys many. This is most likely to hit the makers of PC-compatible computers.

But surely, you may ask, don't we have a native memory manufacturer in Inmos? Yes we do, but it is under considerable financial pressure from its masters at Thorn EMI. They have the capability to produce 1.5μm parts but are restricted to using the existing 2.5 to 3μm because they are not permitted to get the equipment to take advantage, both of their abilities, and of the shortfall in the market.

Dataquest is a marketing research company specializing in the electronics industries and, with a massive range of market reports and intelligence, can make prediction on the future of the industry and how specific sectors affect each other. The European headquarters of this American company is in Centrepoint, London.

National support for transputers

The SERC and DTI have taken an initiative to promote the use of the Inmos transputer. Six regional centres have been set up, including the National Transputer Support Centre in Sheffield. This has the specific task of fostering the engineering applications of transputer and the development of transputer-based products. Under the fatherly eyes of both the University and the Polytechnic of Sheffield, the full time staff can offer help and advice to both academic and industrial users.

Industrial users can take advantage of the equipment and expertise of the Centre and can arrange for research and development work to be carried out in academic institutions. Academic users will be able to consult the staff on technical problems and draw on the pool of equipment which is held in the Rutherford-Appleton Laboratory, Oxford. The Centre also acts as a regional centre for the North-East of England.

Its chief national role is in the maintenance of a library of public-domain software and an index of applications.

Although the Centre is set in Sheffield's Science Park, there is not a blade of grass in sight. The Park has been constructed on derelict ground right in the centre of the City and close to the railway station. Funded jointly by a number of public bodies including the City Council it is planned as a centre of excellence for the promotion of high technology industries in the City and in South Yorkshire. At present the Transputer Centre is the first and only occupant.

Multi-tasking flight simulator

Examples of the power of the transputer are becoming more common, but one that caught our attention at the recent Microprocessor Development Show was a flight simulator program written in Occam for the transputer. What's so special about that? The answer is that four simulators are linked together in a ring and each can signal its position to the others, so it is possible for players to see each other on their screens and indulge in dog-fights as well as controlling their craft. The program was written in a month by engineers at Rapid Silicon.

Steve Gaines of Rapid Silicon says that interest in the transputer is gaining rapidly. His company is currently selling more development systems for it than for many other processors, including the 80386. Some of the applications have not received much publicity but include a system for submarines developed by Dowty/Gresham Lion. The closing of the American plant at Colorado Springs has led to a much "sleeker" operation at Inmos that is beginning to show a profit. Thorn are investigating internal use of the power of the transputer in their research laboratories.

Iann Barron, inventor of the transputer, speaking at Bristol Transputer Centre, one of six set up to encourage the use of the computer chip.

Safety conference

The Polytechnic of Wales is to stage a two-day conference in June on health and safety in electronics – a subject of considerable interest in the Principality, where electronic production is now the biggest single industry. Topics will include repetitive strain injury among factory workers and the handling of hazardous substances in semiconductor processing. Dates are 21-22 June; accommodation will be available on the campus. Details from Dr Derek Robbins at the Polytechnic of Wales, Pontypridd, Mid-Glamorgan CF37 1DL, tle. 0443-480480.

National One takes the air

GEC's National One trunked mobile radio system entered service on 6 April, using an air interface which from the start conforms to the MPT 1343 standard. This means that users will be able to buy Band III equipment from a variety of manufacturers with confidence that it will integrate freely. Mobile units from Storno and Motorola were expected to have been type-approved in time for the starting date, and others are likely to follow. Equipment for the rival Band Three Radio system will have to meet the MPT 1343 standard by 1992.

In a trunked network, users share a common pool of radio channels, through which their calls are routed automatically by the system. Besides maximizing the use of scarce spectrum allocations, this arrangement saves users the expense of installing and maintaining their own dedicated base stations.

National One is the first Band III system able to provide networked coverage. Initially the service is available in the London and Birmingham areas, but GEC's ambitious expansion plans will bring it to most centres of population by the end of next year. under the terms of the Band III licence, the network is marketed to users by independent service providers, to whom GEC acts as wholesaler.

Principal users of the network are likely to be national and regional fleet operators, who will be able to take advantage of a range of voice and data services. To improve their efficiency GEC has developed a microcomputer-controlled dispatcher terminal which simplified the setting up of connections and which queues incoming calls for the operator's attention.

Further details from GEC Communications Networks Ltd, P.O. Box 53, Coventry CV3 1HJ, tel. 0203-433333. For a description of the system, see also Trunked mobile radio in Band III, *Electronics & Wireless World*, December 1986, pp51-52.

Expert index searcher

Imagine switching on your computer and having the following conversation:

Q. "Please tell me your problem or area of interest."

A. "I want to know about high-temperature superconductors."

Q. "I have access to about 200 references; would you like to give a target number of references"

A. "50."

Q. "Would you please be more specific in your area of search"

A. "High-temperature superconductors and magnets."

Q. "There are about 45 references; shall I proceed with the search?"

A. "Yes"

Q. "References exist in Inspec, ESA/IRS; please choose."

...Etcetera.

This conversation can now actually take place and is the result of applying expert system intelligence to a database searcher. Tome Searcher has been developed as the result of research instigated by the British Library. The program 'understands' English. It has a list of keywords that it can recognize and a vocabulary of words that it can ignore. If there are words that it does not recognize, it says so and asks for further details: it will then add them to its vocabulary, if necessary. For example: "Please tell me about desk-top publishing, excluding Apples." "I do not understand Apples, is this relevant to the search?" When it has established that this is a make of computer it will happily continue with the search.

Significantly, there is no manual for the system since, by a number of menus, choices, and questions and answers, it guides the user through the maze of databases until it knows exactly what is required and then finds it. At present it works with a number of databases, and these are selected by the user as being most likely to have the information required. Later versions are expected to know where to find the information and search for it automatically wherever it may be held. Information gathered by the system can be sent back through the telephone line and downloaded to disc. It can also be printed out at the host database and posted.

It stores the telephone numbers and passwords for each database and automatically dials and logs on to it. It uses Boolean algebra to formulate a search strategy from the information provided by the user and translates this into the commands needed by each different database. Words relevant to the search have been suitably truncated so that 'Compute' includes 'computer', 'computers' and 'computing'. It includes its own internal database which lists the subjects covered by the host databases and can automatically estimate the number of likely 'hits' to be found on a specific topic. It needs this part to be updated at regular intervals, and an update disc service is provided with the system. However it is hoped that, in the future, the searcher will be automatically updated by the host database whenever it is accessed.

Another refinement is an automatic monitoring service that will regularly probe the databases and retain any new references to a chosen topic.

The first Tome Searcher to be produced is for electrical and electronic papers, including information technology. It is especially based on the IEE's Inspec, now 20 years old, which contains some three million references culled from over 4000 international publications. ESA has backed the project and their own Information Retrieval Service (ESA/IRS) is also on tap.

Electronics was chosen to launch the system as this is one of the most rapidly expanding areas of new information. There is also a very large number of potential users, with over a million members of the IEEE in the US. Further Searchers are under development for physics, pharmaceuticals, business and finance, and petrochemicals. Research is currently under way to apply the system to sections of the British Library, for example, music manuscripts.

Tome Searcher works on a PC with a hard disc. It occupies about 4Mbytes of disc storage.

Researchers at London University originated the system, which is now produced by its own company, Tome Associates Ltd, working from two centres, West London for the administrative and technical operation and Guildford for commercial exploitation.

Vaccination against viruses

Computer viruses have had much press publicity recently. Now an Oxford company, Sophos, has produced a system to defeat them.

Data viruses contain a machine-code program which can wipe a specific part of computer memory or (hard) disc drive. Any removable disc will also be infected and can pass the virus on to other computers. A 'Trojan Horse' is a programme that leaves a security loophole in the computer system, and there is also a 'timebomb' that can be linked to the computer's calendar/clock and create havoc every Tuesday, or in three months' time. What makes such devices so insidious as that they are disguised as perfectly innocent, even attractive, computer games or utilities which will run normally while infecting the computer.

One recent example of a non-malignant virus was the infection last Christmas of the IBM European network with a program that drew a Christmas tree on the screen. It also looked up all the mailbox addresses within the computer's memory and sent copies of itself to them. Within seconds there were images of Christmas trees on all IBM terminals in the network, all over Europe.

Nearly all the personal computers in the campus of Lehigh University, USA, were infected by a viral COMMAND.COM program. As this is part of the standard MS-DOS it spread very easily and caused unpredictable system crashes. NASA's space physics analysis network has been similarly attacked but details of the effects have been kept secret.

Vaccine is the appropriate name of a program that takes a 'fingerprint' of software that is known to be 'clean'. Fingerprints are themselves encrypted for additional protection. Subsequently a 'diagnose' module of the program is used to check the integrity of the appropriate files.

Prime targets for viruses, Trojan horses and time bombs are the executable files in a computer but Vaccine can protect against corruption of any sort of file, text or binary. These include auxiliary and subsidiary files which are integral to the operation of a program but are not themselves executable. Fingerprinting is performed on valid files using ISO standard 8731 algorithms combined with a data encryption standard to achieve maximum protection of the fingerprints and the files. Vaccine is currently available for all versions of the IBM PC and compatibles, while adaption for VAX/VMS and Unix is under way.

Sophos can be contacted at 20 Hawthorn Way, Kidlington, Oxon OX5 1EZ. Tel: 0865 853668.

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CCIR/5 MODULATOR SPECIFICATION	
Power Requirement	— 240V
Video Input	— 1V Pk-Pk 75 Ohms
Audio Input	— 1V rms 30K Ohms Adjustable .4 to 1.2
Vision to Sound Power Ratio	— 10 to 1
Output	— 6dBmV (2mV) 470-860MHz
Modulation	— Negative
Audio Sub-Carrier	— 6MHz or 5.5MHz
Frequency Stability	— 25 Deg temperature change 150KHz
Intermodulation	— less than 60dB
Sound Pre-Emphasis	— 50us
Double Sideband Modulator(unwanted sideband can be suppressed using TCFL4 Combiner/Leveller)	

CHANNEL COMBINER/FILTER/LEVELLER to combine outputs of modulators	
TCFL2	2 Channel Filter/Combiner/Leveller. Insertion loss 3.5dB
TCFL4	4 Channel Filter/Combiner/Leveller. Insertion loss 3.5dB
TSKO	Enables up to 4 x TCFL4 or TCFL2 to be combined.

WALLMOUNT DOUBLE SIDEBAND TELEVISION MODULATOR

PRICES FROM ONLY £104.53 (excluding VAT & carriage)

Prices

CCIR/5-1	1 Modulator	£104.53
CCIR/5-2	2 Modulators	£159.99
CCIR/5-3	3 Modulators	£226.28
CCIR/5-4	4 Modulators	£292.56
CCIR/5-5	5 Modulators	£358.85

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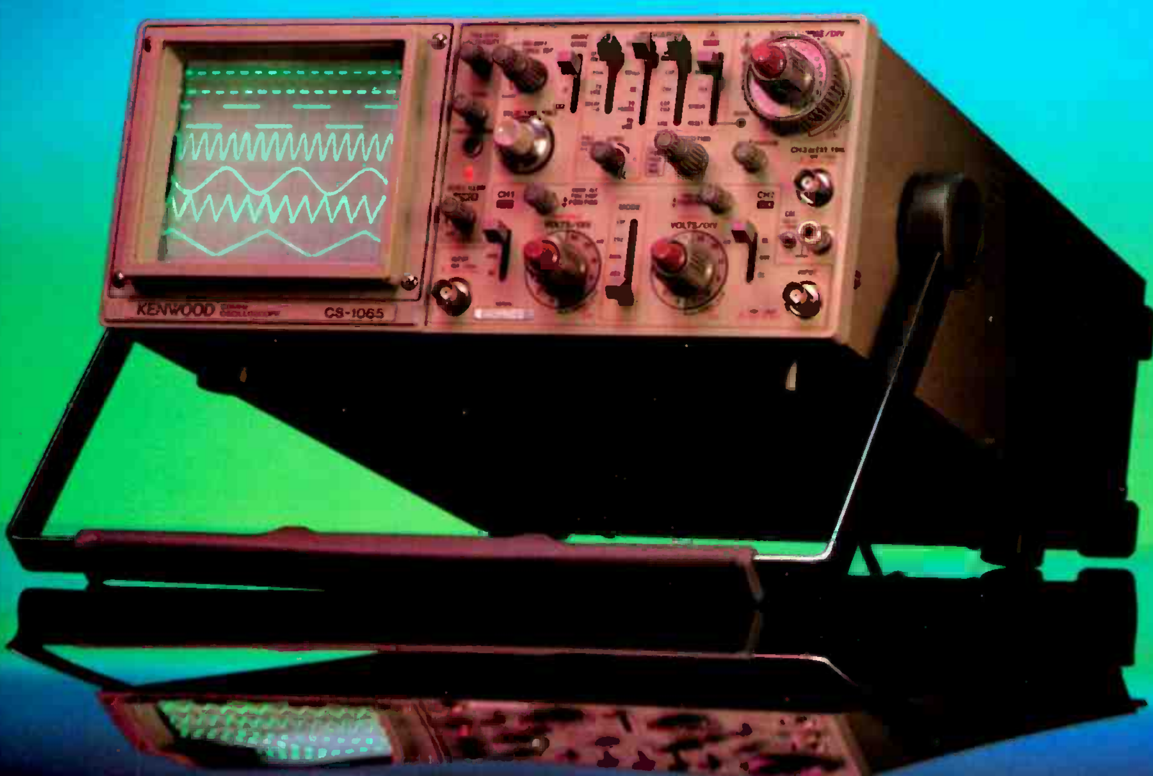
Oh, if you need a translation of the Japanese text, please see below*



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