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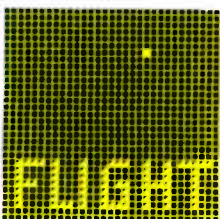
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## SPECIAL FEATURES

### KILLING FIELDS - INTRODUCTION ....96

Electro-magnetic smog generated by computer terminals, domestic wiring and electrical power lines may provide the key to a whole range of life threatening diseases including childhood cancer. This trilogy of articles collates epidemiological (the association between disease and its environment) and biophysical (directly observable cellular effects) evidence from researchers all over the world.

The trilogy suggests that some 10 to 15 per cent of all childhood cancers may be attributable to the magnetic fields associated with electrical wiring inside and outside the patient's home. Other facts include an observed 2.6 times mortality rate from myeloid leukaemia among radio amateurs and an astonishing 13-fold increased incidence of the disease among electrical workers.

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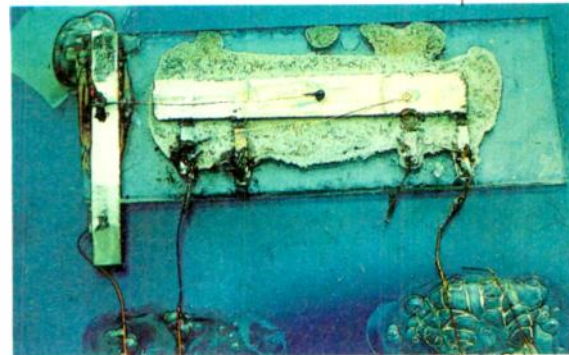
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In next month's issue, Normal computer architecture is rigid and a machine needs to be told the dimensions of a problem before it can begin to work out the solution. Neural networks enable computers to define problems through a learning process and then use the knowledge gained to provide solutions. These architectures have been discussed for years but have consistently failed to deliver their promise. This may be about to change.

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Smoking is hazardous to your health. So is sleeping in an electrically heated waterbed, spending all day in front of a CRT based computer screen, using an electric blanket, or living within the magnetic and electric fields which surround power lines.

They say that smoking kills: not everyone who has ever lit up, but a significant proportion of those who regularly do. The same can now be said - fairly reliably - of electro-magnetic low frequency fields. The evidence which backs this statement can be found in the trilogy of articles appearing in this issue.

The analogy is accurate. A person can smoke 80 cigarettes a day yet live long enough to receive a birthday telegram from the Queen; a less fortunate soul who has never smoked at all may contract lung cancer. In spite of the paradox, medical opinion generally agrees that cigarette smoking causes cancer. When the tobacco companies beg to differ, their arguments sound rather hollow.

Precisely the same can be said of non-ionizing, low frequency radiation. A person can live from the cradle to the grave within the shadow and hum of a 400kV power line yet never suffer ill-effect. The child living next door, who has lived there since birth, may well become a cancer victim. Cancer, leukaemia predominating, accounts for 50% of deaths in the under 15s. One child in 650 children will die from the disease. A child living within the power line field (defined as having a flux density greater than 250nT) is nearly three times as likely to contract the disease as one who isn't.

In the smoking analogy, cigarette consumption and the associated risk factor can be stated precisely: the matter has been in the public domain for years. With only the tobacco industry to fight, money has been available for the studies which provide the evidence. Not much, for the

tobacco lobby is powerful, but some.

The same can't be said for studies into the effects of non-ionizing (read power line) fields. To be fair, the suspicions are more recent than those associated with the effects of tobacco tar. But they have been with us for 15 years and a properly funded and executed investigation into the pathological effects seems overdue.

This won't readily happen because acceptance of the researchers' findings would make the CEBG liable for compensation payable to thousands of people living over and under power line routes. Even greater sums would need to be spent on re-routing cable runs and the other actions required to reduce public exposure to power line fields. In short, EM field exposure would have to be reclassified an industrial health hazard. With privatisation looming, this seems politically impossible.

Behind the power industry lies the Government. Both take public comfort from the results of a limited 1985 CEBG survey, dealt with elsewhere in this issue, into the effects of power lines. It revealed little, which isn't surprising, since out of the 966 children involved in the survey, just 14 lived in houses located in magnetic fields exceeding 100nT. There should be no shelter here. The electricity industry denials will eventually sound as hollow as those of the tobacco companies.

The matter doesn't end here. Cot deaths have recently been linked to high level, low frequency alternating magnetic fields. CRT based VDU terminals seem implicated with teratological effects in pregnant operators, presumably through the stray, pulsing magnetic fields associated with the CRT scanning coils.

People who smoke take a calculated risk. They know the dangers but choose to smoke. The same can't really be said for those who live within the shadow and field of a power line.

Frank Ogden

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## The mystery of the missing bass

It is a well-known fact that if you remove the fundamental tone (and even a few of the lower harmonics) from a complex musical sound, the perceived pitch doesn't change – surprising, when all the textbooks tell us that the fundamental tone defines the pitch. Listening to grand organ music on a pocket radio may not be the ultimate in musical enjoyment, but the absence of bass below 500Hz doesn't transpose Bach's D minor Toccata into some higher key! Pitch and frequency are clearly very different entities.

Common explanations for this phenomenon either assume that we supply the missing tones in our imagination or else that they are somehow physically re-created as a result of non-linear mixing somewhere in the ear. Those who expound the latter idea, however, don't usually stop to wonder why there are no audible mixing products apparent when two or more mathematically-unrelated tones are sounded together at a modest volume. Nor does this theory take into account laboratory evidence showing that when the ear is presented with a complex sound

from which the bass has been filtered out, the hair cells of the cochlea corresponding to the missing low frequencies do not in fact vibrate. So whatever enables us to 'hear' those 32 foot organ stops on a tranny, it isn't non-linearity in the ear.

To resolve this question, C. Pantev *et al.* of the Institute of Experimental Audiology at the University of Munster, FRG, made use of a new technique to analyse the electrical activity in the part of the brain responsible for hearing. It uses an ultra-sensitive magnetometer based on a SQUID (Superconducting Quantum Interference Device). Using the SQUID they were able to pick up the tiny magnetic fields corresponding to electrical activity in 70 different positions inside the brains of 15 volunteers.

The experiment (*Science* vol. 246 486-488) set out to study the brain activity corresponding to three different acoustic stimuli. The first two consisted of pure tones at 250Hz and 1kHz, while the third was composed of the 4th to 7th harmonics only of 250Hz.

All the subjects, of course, perceived

the last stimulus as a rough-sounding 250Hz note, in spite of the fact that no 250Hz tone was present and in spite of special techniques to ensure that there were no combination tones resulting from non-linear interactions.

When the brain signals were measured, however, there was little difference between the pattern of electrical activity due to the 250Hz pure tone and that due to the harmonics of 250Hz. This implies, according to the researchers, that the spatial organization of brain cells corresponds to *perceived* pitch and, moreover, that simple and complex sounds have the same neural mapping. In this respect the brain differs from the cochlea, where sounds translate directly into their corresponding physical frequencies.

Just how the sound processor in the auditory cortex of the brain converts frequencies into perceived pitch is, needless-to-say, another and very much more complex question. Nevertheless, as Pantev and his colleagues point out, this latest work does at least provide new constraints on some current theories.

## Debut of the vigfet

From jugfets to mosfets and beyond, it's sometimes hard to keep up with all the developments in the world of field-effect transistors. But of all the intriguing variations to date, few can be as novel as the vigfet. No blame if you can't guess, but this acronym stands for Vacuum Insulated Field Effect Transistor. It's the brain-child of a team working in the Department of Electrical Engineering and Computer Science at the Massachusetts Institute of Technology and it's an attempt to overcome one of the curses of most solid-state devices, susceptibility to radiation.

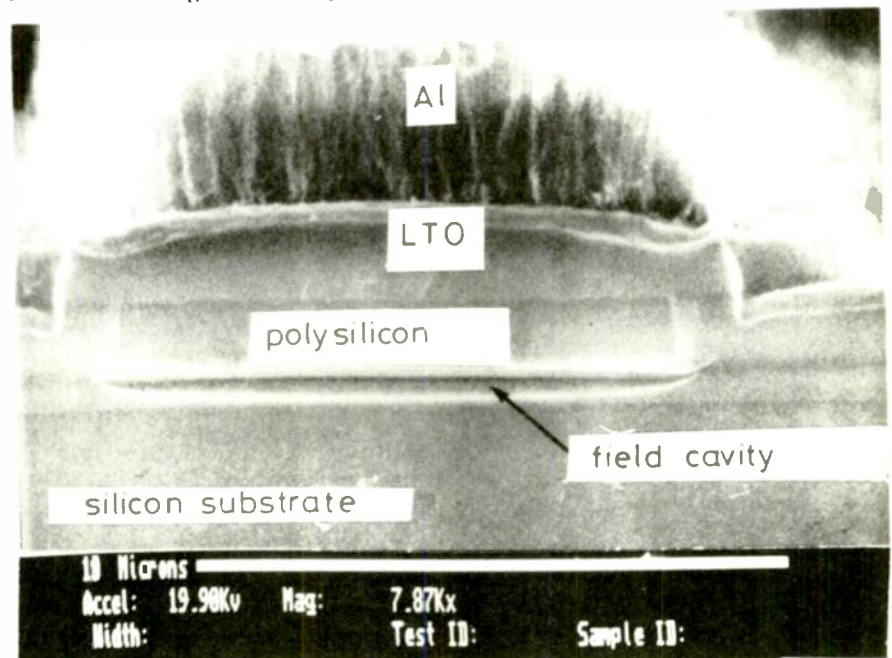
Ionizing radiation affects conventional mosfets by creating a charge in the oxide, something that is effectively sidestepped if the oxide gate insulation is replaced by a vacuum. The authors of the paper (*Electronics Letters* vol. 25 no 23) add that, in addition to being potentially radiation-hard, the vigfet has a useful extra property in that deformation of the gate modulates the drain current of the device. This means that if the structure is designed so as to permit mechanical deformation, the vigfet could be used as an integrated pressure or acceleration sensor.

As yet, the MIT team have only

demonstrated the technical feasibility of manufacturing vigfets using a combination of polysilicon mos processes and micromachining. Alternative processes and tests for radiation hardness

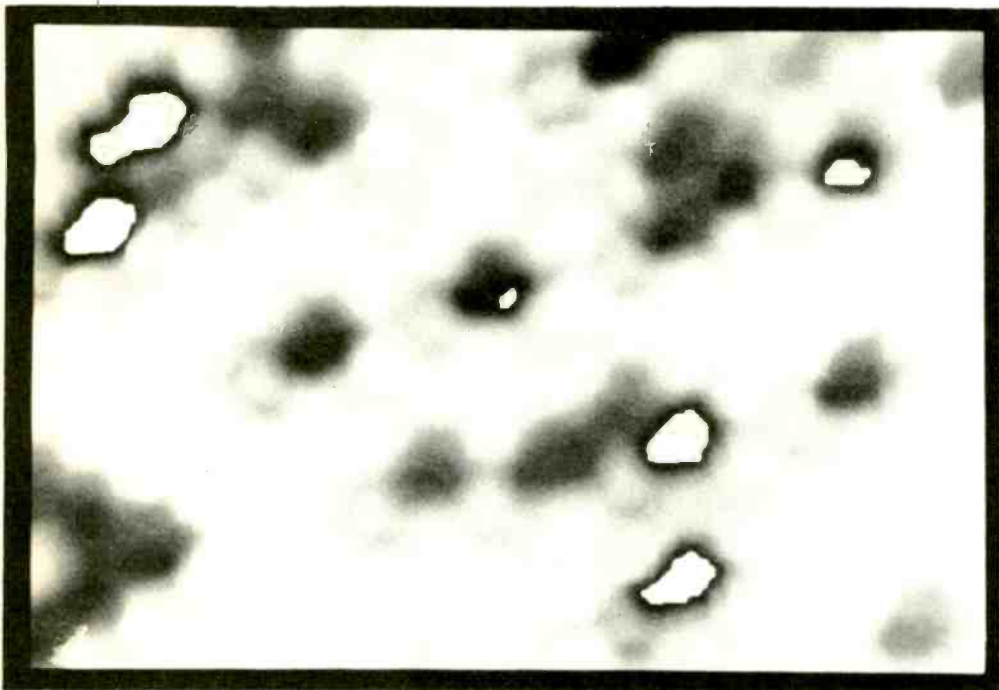
and long-term stability have yet to be undertaken. Nevertheless, this does appear to be a device with considerable potential in the nuclear, military and space fields.

cross section of vigfet infield region, showing sealing of the vacuum cavity.



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## Tunnel diodes by the million

Tunnel diodes, well-known for their high-speed switching properties, are unusual in possessing negative resistance over part of their characteristic curve. Increased applied voltage results in decreased current and vice versa. Most tunnel diodes consist of a heavily doped junction, across which electrons can tunnel (i.e. surmount a potential barrier according to quantum principles) at certain levels of forward bias. Development of tunnel-diode-based devices involves exploiting bias levels where tunnelling occurs and bias levels where it is forbidden. Esoteric though its principles are, the tunnel diode is no more capable of micro-miniaturization than any other junction device.

That could now change following experiments undertaken by A. Golovchenko *et al.* of Harvard University and reported in *Nature* (vol. 342, no 6247). Golovchenko was working, not with tunnel diodes per se, but with a sophisticated instrument, the scanning tunnelling microscope (STM). An STM works by scanning a very fine needle across the surface of a sample under investigation. A small voltage is applied between the needle and the sample, so that when the needle approaches it to within a few atomic radii electrons tunnel across the intervening space, causing a few microamps of current to flow. Since the current is critically dependent on the spacing, the

needle can be made to follow the contours of the sample simply by using a feedback loop to maintain a constant

tunnelling current. In this way, pictures can be synthesised showing surface topography right down to atomic dimensions (see *E&W* February 1989, p.114).

Golovchenko and his colleagues were using this technique to study a silicon surface that had been heavily doped with boron when they observed an unusual phenomenon over some parts of crystal surface. Negative-resistance characteristics of tunnelling effects in the crystal itself seemed to occur whenever the needle to the STM hovered over areas that were free of boron atoms but which were immediately adjacent to boron-occupied positions. What the researchers had found – almost by accident – were tiny tunnel diodes no bigger than  $60\text{\AA}$  square.

This raises the possibility that tunnel diodes could be deliberately fabricated to the scale of atoms and molecules, especially as the STM has already demonstrated another key ability, that of moving individual atoms from place to place.

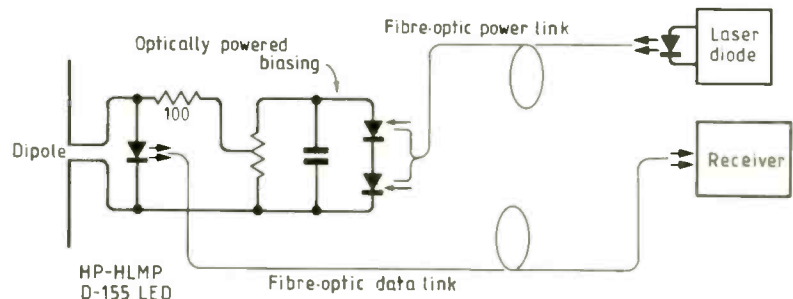
## RFI-proof electromagnetic field sensor

How do you design a probe to measure high levels of RF such as those encountered close to the radiating elements of antennas? One obvious difficulty is that the RF field will induce a voltage not just on the pick-up probe, but on other devices nearby. Accurate measurements are therefore virtually impossible. Another less obvious problem is that the cable

between the probe and the main body of any practical measuring instrument will disturb the RF field and will never itself be totally immune to RFI.

A novel solution to this dilemma is proposed by P.S. Neelakanta

**Interference-proof RF sensor by Neelakanta and de Groff. Based on a drawing from electronics letters.**





## Intelligent toilet

A new electronic toilet, developed in experimental form by three Japanese companies, makes it possible (so they say) to avoid those embarrassing physical examinations we all dread.

Omron Tateisi Electronics Co., Toto Ltd and NTT have come up with a novel hi-tech loo which can measure the user's physiological parameters privately and automatically. It works by dropping a test strip into the toilet bowl and then using optical sensors to determine any colour changes due to sugar or protein in the urine or to blood in, or....

Other features of this programmable privy are sensors to read your blood pressure and heart-rate and a built-in screen to display all the collected data. But lest you imagine that's all there is to this excretory extravaganza, read on.

A spokesman for Omron Tateisi Electronics is quoted as saying: "It is our dream that someday people's homes will be linked via communications lines to a health centre which could monitor the changes in the vital

signs read by the toilet." Curbing his enthusiasm a little, the same spokesman conceded that a more realistic scenario would involve the use of personal smart cards that would be carried by individuals and inserted into a slot in the toilet. This, he said, would

allow each user to keep a running (*sic*) tab on his health.

All I want to know is what the online version would do when I tip a gallon of spent ferric chloride solution down the pan...send a fleet of ambulances?



## New hopes for superconductivity

Until recently, few scientists held out much hope of ever developing practical high-temperature superconductors. The main problem – as previously discussed in these columns – is that all the new ceramic materials lose their superconductivity when called upon to carry a current of more than about 6.5  $\text{KAcm}^{-2}$ . That may seem a lot but it's not enough for many of the dream applications such as super-powerful magnets, motors and transmission lines.

The problem, which perversely seems to get worse with increasing transition temperature  $T_c$ , is a consequence of the behaviour of the superconductors' flux lattices, quantized lines of flux that appear in the presence of a magnetic field. If the current forced through the superconductor exceeds the critical current density  $J_c$ , then the flux lines migrate, creating perceptible resistance.

This seemingly insuperable obstacle may now have been overcome, thanks to a new technique developed by R.B. Van Dover *et al.* at AT&T Laboratories in New Jersey (*Nature* vol. 342 no 6245). Using a crystal of  $\text{YBa}_2\text{Cu}_3\text{O}_7$  they deliberately introduced defects into the crystal lattice by bombarding it

with high-energy neutrons. The resulting evenly distributed defects effectively 'pin' the flux lines in place, allowing a much higher critical current before the superconductivity collapses. Van Dover and his colleagues found that, after neutron treatment, the maximum current that could be passed through the crystal increased by almost two orders of magnitude to  $620 \text{KAcm}^{-2}$ .

Although this work represents the most significant breakthrough for a year or two, it's still not the final answer to the commercial exploitation of high-temperature superconductivity. For although Van Dover believes that uniformly defective crystals should be reproducible, there's a lot to learn before it can be done consistently. Also it would be difficult to see how to introduce high-energy neutrons into a routine fabrication process.

Nevertheless, a hundred-fold reduction in what was being considered a natural and insurmountable obstacle only a few months ago demonstrates that superconductivity is a subject that still has a number of surprising tricks up its sleeve.

Research Notes are by John Wilson of the BBC World Service science unit.

and Dr De Groff of the Department of Electrical Engineering at Florida Atlantic University (*Electronics Letters* vol. 25 no 23): they use a dipole as the pick-up element and connect it directly to a light-emitting diode. RF voltages across the diode produce a glow, the light of which is fed along an optical fibre to a remote receiving device.

The only slight complication is the need to bias the led to the point of conduction, which can also be achieved without the need for wires. Neelakanta and De Groff use a laser diode to feed a second optical fibre, which illuminates a pair of photo-diodes to create a suitable bias voltage.

The whole idea, as can be seen, is extremely simple and works well in experimental breadboard form. The experimenters say it is usable up to about 30MHz (limited mainly by the chosen led) and works well in the near field of an antenna excited by a 100W transmitter. They add that, because of the extremely small size of the sensing head, their instrument offers excellent spatial measurement resolution.

# KILLING FIELDS

Power lines, computers, waterbeds, radar and electric blankets are all implicated in a threat to health which is only just beginning to emerge. Alasdair Philips introduces a trilogy concerned with the effects of non-ionising electromagnetic radiation.

**I**t is only about 100 years since electricity generation started, 70 years since public radio transmissions and 50 years since radar was first used. In the UK, the quantity of power generated has increased approximately 90-fold since 1920. Indeed, it is really only since the 1950s that we began to surround ourselves with significant amounts of electromagnetic energy.

When radar was first introduced in World War II, it was such an important factor in the Allied victory that few raised questions of its biological safety; safety standards were set high enough to allow the military virtually unrestricted use of microwave and high-frequency radiation. American scientific reports from the time suggesting that microwave radiation might cause leukaemia, cataracts, brain tumours and heart disease were ignored.

When maximum exposure levels were set in the 1950s, they were mainly based on how much external power could be dissipated on the surface of the human body without causing a significant rise in body temperature.

The validity of these and subsequent safety standards across the electromagnetic spectrum is now being challenged, both within the scientific community and, increasingly, in the courts. This has been brought about by the considerable number of research reports linking low-level alternating electric and magnetic fields with a

variety of serious adverse health effects.

Particularly worrying are the reports about the effects of 50Hz and 60Hz power-line fields, low-frequency pulsed radar systems and high-power ELF communication systems.

Here is a selection of some of the report conclusions.

— The risk of dying from acute myeloid leukaemia is increased by 2.6 if you work in an electrical occupation, especially if you are a telecommunication engineer or radio amateur<sup>1</sup>.

— Service personnel exposed to non-ionizing radiation when compared with their unexposed colleagues were almost seven times as likely to develop cancer of the blood-forming organs and lymphatic tissue and more than four times as likely to develop thyroid tumours; younger personnel between 20 and 29 had a 550% greater risk of being stricken with cancer<sup>2</sup>.

— 10 to 15% of all childhood cancer cases might be attributable to power-frequency fields found in their homes<sup>3</sup>. For children who live close to high-current wires the risk increases to more than five times the risk of those who do not<sup>4</sup>. The incidence of childhood cancer<sup>5</sup> more than doubles in homes where the average 60Hz magnetic field strength is over 300nT.

— Significantly more miscarriages are reported by electric blanket and heated water-bed users during winter months<sup>6</sup>.

— 60Hz power-line fields produce a



## NON-IONIZING RADIATION

large suppression of T-lymphocyte cells to mark and kill cancer cells<sup>7</sup>.

— 100mT 45Hz magnetic-field exposure showed a rapid build-up of serum triglycerides, an accepted warning of likely heart problems<sup>8</sup>.

— 100% increase in miscarriages was found when VDU operators were compared with non-working pregnant women in a sample of 1593 women<sup>9</sup>.

— A Canadian power utility has made an unprecedented offer to buy a home within 50m of a 230kV power line right-of-way (ROW). The UK does not even acknowledge the need for ROWs and still allows houses to be positioned directly under high-voltage distribution cables, subject to a nominal clearance<sup>10</sup>.

— Clinical depression and suicides were closely linked with living near UK power lines<sup>11</sup>.

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# KILLING FIELDS

## The epidemiological evidence

The threat posed by low frequency fields emerged initially because a researcher, looking for environmental factors in childhood leukaemia, observed a link between low voltage, high current power lines and disease occurrence. Cellular evidence now supports the findings but epidemiology still leads the argument. By Simon Best.

Today living systems are exposed to a level of man-made electromagnetic fields (EMFs) in all aspects of modern life to a degree never experienced before on this planet, most of it resulting from technological advances over the past 40 years. Whether at home or at work, EM fields generated by domestic wiring, overhead high voltage lines and occupational equipment, as well as other environmental sources such as radar, microwave communication systems, radio and television broadcasting, cellular telephones, and the ubiquitous VDU, all contribute to an individual's cumulative chronic exposure.

Growing awareness of this situation has led to the question being debated and researched, for at least the past 30 years by Western scientists (and even longer by the Russians), as to whether and to what extent this chronic exposure is harmful. The often heated debate continues but over the past few years there are signs that certain scientific and legislative authorities, particularly in the United States, are beginning to accept the need for revised protective regulations and safety legislation, despite continued official denial or ambivalence in some quarters, notably in Britain.

The UK's National Radiological Protection Board (NRPB) recently published its final guidelines<sup>1</sup> on restricting public and occupational exposure in both the extremely low frequency (ELF) 50Hz power frequency and the much higher frequency RF and microwave parts of the electromagnetic spectrum. Although these go further than any previous such guide-

lines, they can be criticized on a number of counts, as will be described below. Also, they are proposed only as guidelines, with decisions on new legislation left to the relevant minister; significantly, no mention of electromagnetic fields was made in the Government's recent proposed Green Bill.

Bioelectromagnetics is the study of the effects of electromagnetic fields on biological systems and an understanding of significant events and issues in its recent history is necessary to appreciate current debate and developments.

*"A significant trend in risk of suicide was shown with increasing field-strength."*

Research on the possible harmful effects of EM fields began to appear in earnest after the war, partly due to the advent of radar, emerging as an issue in the 1960s mainly as a result of Russian work<sup>2</sup>.

Observed health problems affecting switchyard workers and others occupationally exposed to EM fields led the Russians to develop a standard for public exposure to microwave and RF EM fields that was, at  $10\mu\text{W}/\text{cm}^2$ , 1000 times lower than that considered safe in America and other Western countries.

The Americans, however, developed their guidelines, such as they were, from a model of human absorption of electromagnetic energy that took account only of the effects of heating body tissue — the so-called thermal model. In the 1950s, Professor Herman Schwan, a physicist who arrived in the US after the War and has been based at the University of Pennsylvania ever since, mainly funded by the Department of Defense, invented the microwave oven for use in submarines. Schwan used metal balls and flasks of salt water to model the human body's ability to dissipate heat to estimate a danger level of exposure. Observing that significant heating only occurred above 100mW, he incorporated a safety factor of 10 and, in 1953, proposed a safety limit of  $10\text{mW}/\text{cm}^2$  for human exposure.

By 1957/8 industry and the military had, with little real debate or further experimentation — and none for non-thermal effects — accepted the level as an informal guideline. In 1965 the Army and Air Force formally adopted the  $10\text{mW}/\text{cm}^2$  limit and one year later the American National Standards Institute (ANSI) accepted it as an occupational exposure standard. The ANSI decision is remarkable, since Schwan has consistently maintained that his dosage limit is safe for probably no more than an hour.

As will be discussed below, current debate on revising the ANSI standard is suggesting reductions by between 10 and 100 times. And it is the growing and accumulated evidence supporting the reality of non-thermal effects that has fuelled this

debate, much of which, in the face of opposition and limited funding, has been finally carried out over the past decade.

The first well-controlled Western study linking power line fields and childhood leukaemia was reported by University of Chicago researchers Drs Nancy Wertheimer and Ed Leeper in 1979, from a case-control study of 344 children aged 18 and under in the Denver area<sup>3</sup>. Using a wire coding and configuration assessment of the high-current electric cables near the children's homes to indicate 60Hz magnetic-field exposure, they found a statistically significant increase in childhood cancer in the exposed children, a relationship that increased with proximity.

In the UK in the same year an Albrighton GP, Dr Stephen Perry, collaborated with three US researchers in New York to study suicide in the Shropshire/Staffordshire area. He measured the residential magnetic-field strength outside the front door of homes and found significantly higher fields ( $0.1\mu\text{T}$  or more) at those of suicides as opposed to controls (less than  $0.1\mu\text{T}$ ); the results were published in 1981<sup>4</sup>. A significant trend in risk of suicide was shown with increasing field strength.

A year later Tomenius, in Sweden, reported a two-fold increase in the incidence of childhood cancers in homes within 150m of visible 200kV power

*Wertheimer and Leeper ... observed at least a two-fold increase in adult leukaemia linked to fields from wires near the home.*

lines, his work being published in a revised form in 1986<sup>5</sup>. (As in the UK, Europe uses a 50Hz power frequency.) At addresses where the magnetic field exceeded  $0.3\mu\text{T}$ , the relative risk was 2.7 (95% CI 1.2-5.9); when the sample was restricted to those living at the same address since birth, the relative risk rose to 5.6 (95% CI 1.8-17.9).

One year before Wertheimer and Leeper's study, the New York Public Service Commission reached a decision in a hearing concerning two proposed 765kV lines to run from the Canadian border to locations in New York State. After an acrimonious hearing, the New York Public Service Commission permitted the

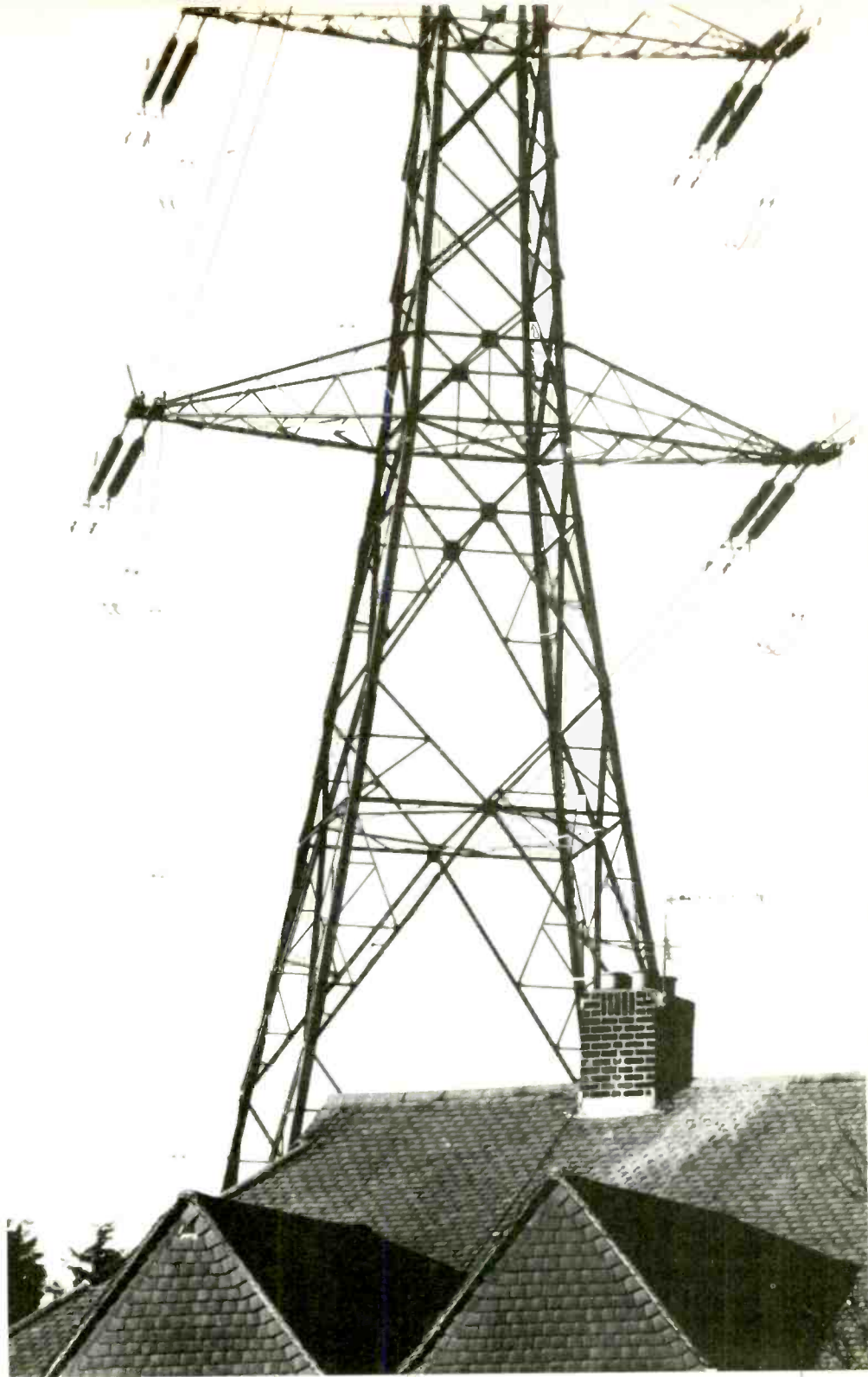
lines to be erected but only on two conditions: that the power utilities involved fund a five-year, five-million-dollar research project, known as the New York State Power Lines Project (NYS-PLP), to study possible hazards from power-frequency EM fields; and that a 350ft right-of-way (ROW) corridor either side of the lines be established within which no human dwelling was to be permitted, as already existed for 345kV lines.

Almost simultaneously, a public inquiry in the UK was taking place into the proposed re-routing of power lines near the village of Innsworth, Gloucestershire. Its eventual result, however, was very different, with the objec-

tion being overruled by the two inspectors (one each from the Departments of Energy and the Environment), but without any independent medical assessment of the evidence.

That illustrates the stark contrast between legislative progress in the US compared to the UK. Today, 10 years later, despite seven American states having now adopted similar ROWs to those in New York state, no such recognition is given in the UK of the need for ROWs around power lines.

The results of Wertheimer and Leeper, Perry, and Tomenius, as well as the setting up of the NYSPLP, led to a growing number of studies of both residential and



## NON-IONIZING RADIATION

occupational exposure to ELF EM fields. Wertheimer and Leeper extended their research to adults and observed at least a two-fold increase in adult leukaemia linked to fields from wires near the home<sup>6</sup>, while others found correlations with occupational groups exposed to ELF fields, such as electrical and electronics workers and repairmen, and leukaemia in general; Milham<sup>7</sup> and Stern<sup>8</sup> in the States, Coleman and colleagues in the UK<sup>9</sup> and Pearce in New Zealand<sup>10</sup>.

Similar occupational studies have linked pharyngeal cancer<sup>11</sup>, eye melanoma<sup>12</sup>, and primary brain tumour<sup>13,14</sup>. One of the most consistent connections was observed with myeloid leukaemia, with studies from the UK<sup>15,16</sup>, Sweden<sup>17</sup> and the US<sup>18,19</sup> all finding an elevated risk.

Some of the results of the occupational studies have been criticized on the basis that workers might have also been exposed to fumes and substances (such as PCBs) then used in electrical components or assemblies. However, in one of the US studies of myeloid leukaemia, Milham<sup>19</sup> studied radio amateurs and found an increased risk of myeloid and unspecified leukaemias in both those with and without occupational exposure, thus supporting the hypothesis that it is the electromagnetic fields themselves that are the hazard.

Meanwhile, on the question of residential exposure and cancer, the CEEB had, by 1985, carried out only one piece of research, a pilot study of childhood leukaemia reported at a conference<sup>20</sup>, an inconclusive result which the authors

nonetheless admitted had certain shortcomings and of which a revised version has apparently now finally been submitted for publication.

During this time, other laboratory work was confirming the ability of low-intensity EM fields to cause biological effects below the thermal level and revealing some frequency-specific actions of modulated fields. Dr Ross Adey and his co-workers have demonstrated the effect of specific modulated frequencies on the efflux of calcium ions from cats' brains<sup>21,22</sup>, which has been confirmed by Blackman and others<sup>22,23</sup>.

The combination of the highly suggestive epidemiological results and the growing evidence from animal and cellular studies led, in 1986, to a landmark pro-

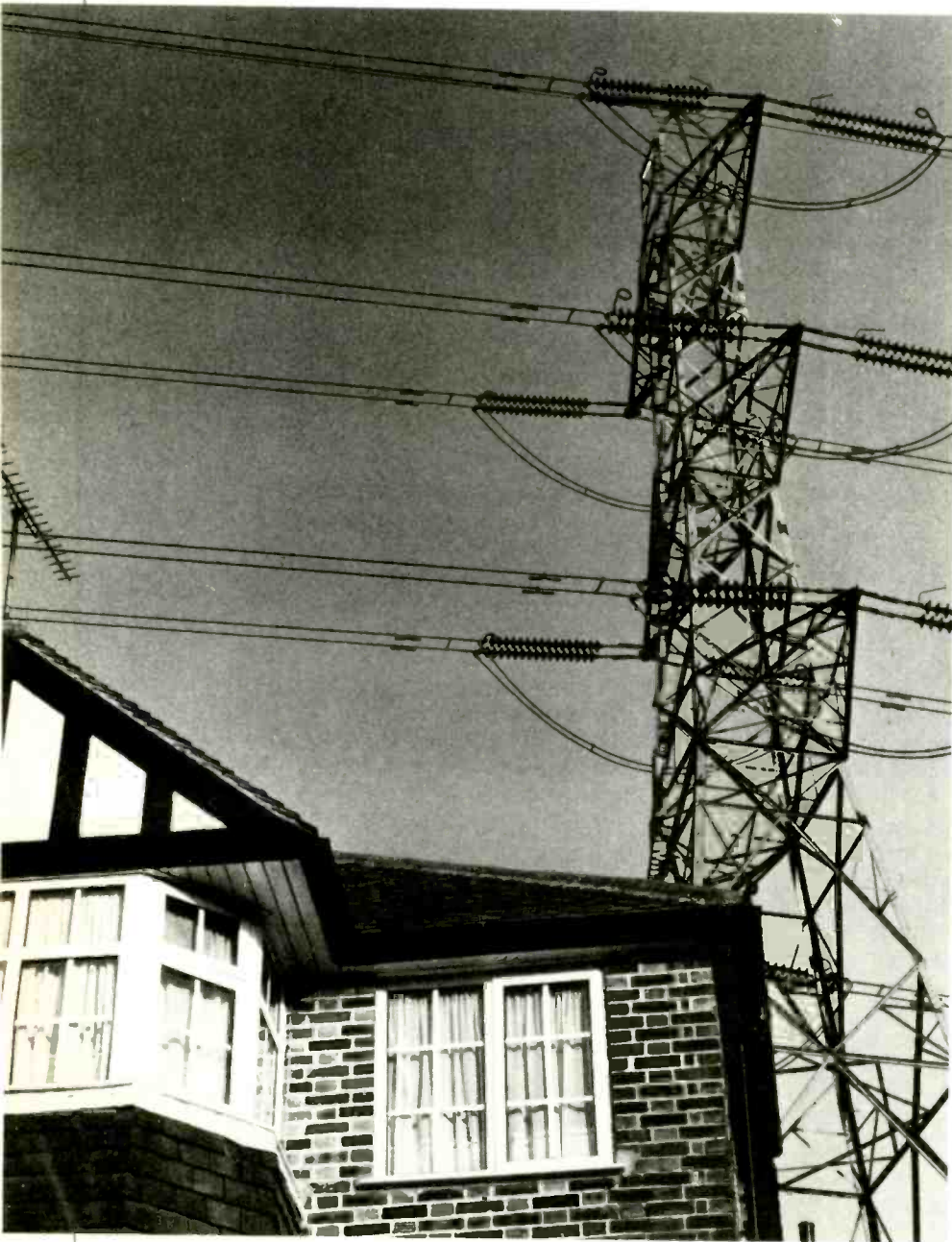
*"... if one accepts a causal link between power-line magnetic fields and cancer, as much as 10-15% of all childhood cancer cases might be attributable to such fields."*

nouncement by the American Advisory Committee on the Non-Thermal Effects of Non-Ionizing Radiation.

Reporting to the United States National Academy of Sciences' National Research Council, it finally accepted the reality of non-thermal effects and stated that "Abundant fragmentary evidence has been presented in support of possible biological effects from non-ionizing radiation, at both transmission and microwave frequencies. These effects often appear to be unaccompanied by macroscopic thermal changes"<sup>24</sup>.

The report drew the distinction between a biological effect and the point at which it becomes a hazard and stopped short of discussing when this might occur, but the announcement was a significant turning-point in the continuing debate.

A further significant event occurred on July 1, 1987 when the New York State Power Line Project finally reported amid wide media coverage<sup>25</sup> (a copy resides in the House of Commons library). Of the 17 funded studies, 12 reported significant



findings and one in particular attracted public attention: an attempted replication of Wertheimer and Leeper's early study by Dr David Savitz, at the University of North Carolina, using an improved experimental design. His results confirmed their general findings, showing a two-fold increased risk of childhood leukaemia linked to measures of magnetic field from external wiring configurations at a cut-off of  $0.2\mu\text{T}$ , and showed that these fields and not those from appliances inside the house, which fall off sharply with distance, were the primary determinants of the increased cancer incidence. He has since refined and updated his results and these confirm his original findings<sup>26</sup>.

Savitz was able to show that magnetic-field measurements correlated with the

*"...despite seven American states having adopted ... rights of way ... no such recognition is given in the UK of the need for ROWs around power lines."*

wire codes used by Wertheimer and Leeper and that other possible confounders, such as smoking and socio-economic status, did not appreciably change the results.

The final report concluded that if one accepts a causal link between power line magnetic fields and cancer, as much as 10-15% of all childhood cancer cases might be attributable to such fields.

In their final summing up, the authors of the NYSPLP report stated that "a variety of effects" of EM fields has been indicated and that "several areas of concern for public health have been identified". The first of its six major recommendations stated that "There should be a major research effort on means of power delivery that would reduce magnetic field exposure". This was based on the finding that it is the magnetic field that has been mainly implicated as a promoter, as opposed to an initiator, of cancer.

By 1987 the growing public concern had led to some seven US states introducing maximum electric field levels both within and along the edge of power line rights of way, which themselves varied

from 100 to 350ft, depending on the state and line voltage. (The maximum transmission line voltage in the US is 765kV.) Typical maxima for the field within an ROW vary between 7 and 9kV/m and along it, between 1 and 3 kV/m. Legislation is pending in other states, while Florida became the first state, in January 1989, to introduce a maximum magnetic field along a ROW, of  $20\mu\text{T}$  and  $15\mu\text{T}$  for 500kV and 230kV or less power lines respectively. No such legislation exists in the UK.

The NRPB's Guidance on exposure to time-varying EM fields below 300GHz, published in May 1989, sets a guideline for frequencies below 100Hz of 12kV/m for electric and 2mT for magnetic fields for both public and occupational exposure of any duration<sup>1</sup>.

The NRPB issued their advice in response to guidelines recommended by the International Non-Ionising Radiation Committee of the International Radiological Protection Association<sup>17</sup>, which differentiated between occupational and public exposure, a distinction the NRPB rejected, and has recommended 10kV/m and 0.5mT (occupational) and 5kV/m and 0.1mT (public) respectively for continuous exposure.

Although accepting the reality of athermal biological effects, "...particularly of magnetic fields, at all levels of biological organisation...", the Board considers that "...it is not possible to say with certainty or quantitatively whether this evidence has any implications for human health".

As for the epidemiological evidence, the NRPB believes that if the risks of occupational and population exposure to EM fields are real, "...then they are within the range regarded as tolerable, and should not unduly concern individuals". The NRPB based their view on advice from the Medical Research Council's Non-Ionising Radiation Committee which, at a meeting on January 27, 1987, expressed the opinion of members that "...epidemiological studies purporting to demonstrate a correlation between exposure and incidence of neoplasms and congenital abnormalities were inconclusive, except where substantial rises in core temperature had been induced in experimental animals..." "Also, there was no convincing experimental evidence demonstrating that exposure to electromagnetic fields, at field strengths normally encountered, directly caused neoplasms or congenital abnormalities; some experiments at which such a link had been suggested were likely to have involved substantial (i.e. more than  $1^\circ\text{C}$ ) increases in temperature of the cells under investigation".

Not only do the MRC-NIRC and NRPB clearly discount the epidemiological studies already mentioned, but presumably also the further results that had been reported by the end of 1988. Following up his 1985 study, Milham<sup>28</sup> observed that a sample of 2485 radio amateurs showed a significant excess of deaths due to acute myeloid leukaemia (AML).

This followed a combined analysis by Savitz and Calle<sup>29</sup> of 11 different occupational data sets that concluded that telegraph, radio and radar operators had 2.6 times the risk of AML and twice the risk of acute leukaemia as other workers. Power and telephone linesmen also had a greater risk of developing AML. Since then, Linet and her co-workers have reported almost twice the expected frequency of chronic lymphocytic leukaemia in male Swedish electrical workers<sup>30</sup>.

An astonishing 13-fold increased risk of brain tumour in electrical utility workers was revealed by Speers<sup>31</sup> at the Center for Disease Control in Atlanta, Georgia. The risk of brain cancer among other occupations grew linearly with the probability of EM field exposure on the job. Her findings corroborate an earlier report<sup>13</sup> of excess brain tumours in electrical workers.

A further criticism of occupational studies has been that certain levels of exposure have been assumed for electrical workers, with few actual measurements being taken. Bowman and his colleagues<sup>12</sup> measured such fields and reported that they were "...significantly above the levels encountered in residences and offices". Among those exposed to the highest magnetic fields were electricians working with industrial power supplies; underground and overhead power line workers; welders; and transmission station and distribution substation operators. Most exposure varied between 1 and  $5\mu\text{T}$ , although some exceeded  $10\mu\text{T}$ . By comparison, residential exposure was usually below  $0.1\mu\text{T}$ .

Among recent residential studies, GP Dr Stephen Perry<sup>32</sup> published correlations between the magnetic-field exposure of people living in multi-storey blocks (of nine storeys or more) in Wolverhampton with the incidence of heart disease and depression. Magnetic field strengths measured in all 43 blocks with a single rising cable showed very significantly higher readings ( $p < 0.0002$ ) in those apartments categorized as "near" the cable, averaging  $0.315\mu\text{T}$  (highest:  $0.377\mu\text{T}$ ) against  $0.161\mu\text{T}$  (lowest:  $0.148\mu\text{T}$ ) in the "distant" apartments. In line with these measures, significantly more "...myocardial infarction, hypertension, ischaemic heart

disease and depression..." was reported in the those living near the cable.

A further provocative finding was that, if only those blocks with underfloor or storage electric heating were considered, the proportion of cases of "depression" living in flats near the rising cable rose by 82%. (Wertheimer and Leeper have recently linked increased miscarriage rates with EM fields from ceiling-cable heating; see below<sup>31</sup>.)

It is interesting that even Perry's lowest measurements of fields in apartments distant from the cable are 50% above the average residential fields measured by Bowman, while his average 'near' readings were over three times Bowman's figure.

It is also worth noting that when Savitz revised and refined his original data on childhood leukaemia<sup>26</sup>, he found that, whereas when he had used a 0.2 $\mu$ T cut-off for classifying the 60Hz exposed group he had observed a relatively weak, if two-fold, association between measured magnetic field and leukaemia, when he increased the cut-off to 0.3 $\mu$ T, the risk became "...notably larger".

Thus, Tomenius', Savitz' and Perry's (two) studies together indicate that there may be a residential level between 0.2 and 0.3 $\mu$ T at which chronic power-frequency EM field exposure begins to manifest as a recognised clinical condition; in which case, occupational levels of between 1 $\mu$ T and 5 $\mu$ T and above, as measured by Bowman, may represent a considerable hazard, despite exposure being confined only to working hours.

Currently the NRPB is recommending a level of 2mT for both public and occupational magnetic-field exposure, approximately 10 000 times above the levels indicated by Savitz, Perry and others as hazardous. But what is equally disquieting is that in 1986, in a set of proposed standards on which the NRPB invited comments<sup>34</sup>, it was suggesting both one set of standards for workers and two different sets for the public: for workers (two hours exposure per day), 30kV/m and 1.88mT; for the public, 12kV/m and 0.76mT (up to five hours per day) and 2.6kV/m and 0.174mT for continuous exposure.

With the published research after 1986 increasingly pointing to an EM field hazard both occupationally and residentially, particularly from magnetic fields as low as 0.2-0.3 $\mu$ T, as outlined above, one must ask on what basis did the NRPB, three years later, decide to recommend that public and occupational continuous exposure levels be revised upwards, in the case of continuous residential exposure to electric and magnetic fields by, respectively, some five and ten times?

Following Perry's investigation of depression, a further study of depression and chronic headache was carried out by another British GP, Dr David Dowson, in the Southampton area<sup>35</sup>. Giving a questionnaire to patients living within various distances of overhead lines and a control group living three miles away, Dowson found that 15 in the former group versus one in the latter reported recurrent headaches, the highest number (10) living at 80-100m from a 132kV line. Nine patients in the study group reported depression (seven lived within 40m of the lines), as against only one in the control group. No measurements of electric or magnetic field were taken.

In the US, Wertheimer and Leeper, in a study first presented to the New York Academy of Sciences in 1984, reported that pregnancies among couples using electric blankets were more likely to end in miscarriage than those among couples who did not heat their beds electrically<sup>36</sup>. They found a trend toward slower foetal development among babies born to parents using electric blankets or water beds, which generate magnetic fields of 1.0-1.5 and 0.3-0.4 $\mu$ T respectively.

The researchers observed a clustering of spontaneous abortions from September to June among electric blanket users; for those using either electric blankets or water beds the miscarriage rate was significantly higher during the September-June period. No such seasonal pattern was observed among non-users.

Wertheimer and Leeper implicated electric blankets in a further study<sup>37</sup> in

which they re-analysed the apparently negative results of Stevens on the incidence of acute non-lymphocytic leukaemia in adults exposed to ELF fields residentially, originally funded as part of the NYSPLP.

Using Stevens' data, they were able to assess the chronic use of electric blankets, waterbed heaters and electric mattress pads. By taking these and other refinements into account, Wertheimer and Leeper calculated that the risk of leukaemia in those exposed to EM fields from either power lines or electrically heated beds rose 50-90% and, if exposed to both, by 110-260%. Most recently, Wertheimer and Leeper, in an attempt to distinguish heating from EM field effects, have also linked miscarriage and domestic EM fields from ceiling cable heating<sup>38</sup>.

It has been hypothesized that electric blankets may interfere with the menstrual cycle by affecting the pineal gland's secretion of melatonin, which in turn may also led to depressive states in men and women. A study is presently under way at the Yale School of Medicine on the prevalence of electric-blanket use in a group of 4000 pregnant women to determine the feasibility of studying the growth of children exposed to EM fields in utero.

Regarding adult leukaemia, Wertheimer and Leeper have extensively analysed the cancer incidence among adults living near high-current power lines in and around Denver, Colorado<sup>39</sup>. They found that certain cancer subtypes, especially nervous-system cancers, were associated with two measures of exposure to 60Hz magnetic fields. Both those exposed occupationally and residentially showed similarities in the subtypes they contracted.

In a further memorandum, the researchers discuss a possible explanation for why some studies have reported no linear increase in cancer in children with increased intensity of EM field exposure prenatally<sup>40</sup>. They confirm that, in their own and other studies, moderate exposure prenatally was associated with increased cancer after birth, whereas extreme exposure prenatally was not.

They hypothesise that this occurs because magnetic fields "...can have an adverse effect on tissue development which, if it is severe and occurs in the first trimester of pregnancy, may often lead to prenatal abortion rather than postnatal cancer".

Clearly, if valid, their suggestion may also help explain some of the contradictory findings on leukaemia clusters and ionizing radiation sources in the UK, notably nuclear reprocessing and military installations. Synergistic interactions between

*"Abundant fragmentary evidence has been presented in support of possible biological effects from non-ionizing radiation, at both transmission and microwave frequencies. These effects often appear to be unaccompanied by macroscopic thermal changes."*



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 TF2356 level oscillator 20MHz £400  
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 TF2600 millivoltmeter AF 1mV-300V fsd £75  
 TF2600B video voltmeter 1mV-300V fsd £175  
 TF2604 electronic multi-meter £150  
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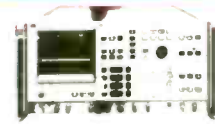
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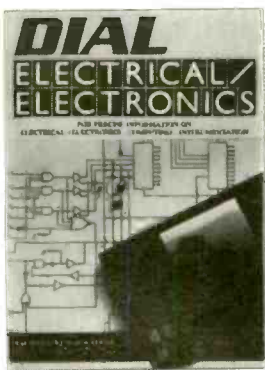
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ionizing and non-ionizing radiation generated around such sites (the latter from the power lines that often originate from such locations) should also not be overlooked.

All of which does not, apparently, impress the NRPB, whose safety guidelines are firmly based only on thermal considerations, although their May 1989 document states that they intend to publish a "...review of the existing biological and epidemiological evidence in the near future".

Not surprisingly, the CEBG tends to hold a similar view regarding the lack of hazard from power line or domestic wiring EM fields. However, in March 1988, possibly galvanised by Savitz' results and the NYSPLP Report in the previous year, they announced a £500 000 research project on ELF EM field bio-effects, involving studies of their own staff, childhood leukaemia, and domestic measurements. But no results are yet available and may not be for some time.

When evaluating US and UK residential research, one needs to consider the differences in the distribution of power to homes between the two countries. In the US, transmission lines carry up to 765kV, while poles carry local distribution wires down the streets and at intervals also carry transformers which step down the 7.6kV area feed to 115V for domestic use.

Indeed, it was the clustering of childhood cancer cases in homes at certain distances from these pole-mounted transformers and associated 3-phase wiring which first caught Wertheimer's attention in the mid-1970s. From these, a single-phase supply then enters the house half way up the building, very often at or near the bedrooms.

By contrast, in Britain transmission lines carry 132, 345 or 400kV, with most domestic supply arriving underground, having been stepped down from the area substation by smaller local transformers (from 33 to 11kV, and from 11kV to the domestic 240V). The cables, carrying the wires in a close, helical arrangement, thus generating a minimal unbalanced current, then enter the house through the basement or ground floor to connect to a meter (except in high-rise blocks, where they run up the side of the building).

However, this is not always the case, as in parts of Norfolk, Suffolk and other rural areas, where supply arrives on poles down the streets, as in the United States. Nonetheless, with both methods, significant magnetic fields in the home can be generated by unbalanced ground return currents.

Because some have argued that these differences in mode of domestic supply and associated EM fields may explain the

generally more positive American residential study results against the relatively few but more negative or ambivalent UK results<sup>30,41</sup>, it could be very illuminating if the CEBG or other researchers were to compare the incidence of major and minor illness (from cancer, heart disease and immune system problems to miscarriage, depression and sleeping problems) in samples of both adults and children living in homes supplied by the two different methods.

In Myers' preliminary results<sup>20</sup> of childhood cancer in the north of England, of which a revised update is apparently to be published shortly, some 7% of the controls lived within 100m of an overhead power line; the relative risk for those living within 50m was a non-significant 1.25 for leukaemia and lymphoma (95% CI 0.5-3.1), and 1.61 for solid tumours (95% CI 0.6-4.6). Criticism of the small number of exposed subjects and other shortcomings must await the final published version.

McDowell's cohort study<sup>41</sup> of 7631 people living in East Anglia within 30m of an overhead power line or within 50m of a transformer substation found a significant excess in lung cancer in women though not in men, although no smoking data was available. For those living within 15m of a source, the standardized mortality ratios were higher for lung cancer, leukaemia and other lymphomas, though numbers of deaths were small. The results applied mainly to substations, since only 0.2% of the sample lived within 30m of an overhead power line.

The inconclusive results of Coleman and colleagues in the recent publication of a study, first reported in 1985, of leukaemia in those living near overhead power lines or substations in four London boroughs<sup>42</sup> emphasizes the problems of estimating exposure and obtaining a sufficient sample to provide a meaningful result. In the study only 0.6% of subjects lived within 100m of a power line, whereas over 40% lived within 100m of a substation. Nonetheless, for those under 18 the relative risk of leukaemia from residence within 50m of a substation was in fact higher than in adults (RR=1.5, 95% CI 0.7-3.4).

Besides the problem of sampling, any future residential studies must now also consider the occupational exposure of the working adults involved, given the many studies linking electrical occupations with increased risk of various cancers (and vice versa for occupational studies). Exposure to other known environmental hazards must also be controlled for, including the increasingly recognised hazard of (ionizing) radon. The location of a child's

*... a sample of 2485 radio amateurs showed a significant excess of deaths due to acute myeloid leukaemia.*

school near overhead power lines or substation would also be significant.

But the question one still has to ask is whether there is already enough suggestive evidence on which to recommend some preventive action. Epidemiological studies are rarely conclusive, but when the majority of occupational and residential studies, despite differences in design and possible confounding variables, seem to point in the same direction, perhaps it is time to err on the side of caution and, for example, to call for a moratorium on the erection of power lines over homes and schools, and vice versa.

The CEBG is unlikely to accept such a proposition, particularly with the implications for its looming privatisation, without some form of exemption from legal liability. But if a system of no-fault compensation could be introduced, as exists in countries such as New Zealand and Sweden, whereby the state accepted basic responsibility for treating and possibly compensating people exposed to such a hazard, a way forward acceptable to the CEBG and local area boards and favourable to the public might be found.

With some US and UK researchers publicly stating that they would not live under a power line, perhaps the CEBG might at least be required to offer to purchase homes under or very near power lines at market value to resell to those prepared to take the risk, as a utility in British Columbia in Canada recently did.

Certainly, long and expensive litigation, as has occurred in the US, may only serve to entrench both sides and delay help for those at risk, though it has definitely brought the issues to the attention of the public and the media there. The case need not be that the evidence is conclusive, merely that it is now sufficient to warrant certain precautionary measures, both for domestic and occupational exposure. (Even the NRPB has confirmed that revised exposure guidelines will be published sometime in 1990.)

Regarding the latter, the Industrial Injuries Advisory Council (IIAC) will take some persuading, it would seem, judging by their opinion on the hazards of

non-ionizing radiation from various occupational sources<sup>4</sup>. Their statement that "The available evidence indicates that chronic low level exposure to non-ionizing radiations appears to be generally harmless" would be greeted with something approaching derision by many researchers, even taking account of its date of consideration in March 1987.

Whether or not the CEEGB disappears, the problem will remain for the private transmission and distribution companies, who can no longer claim ignorance of research findings and will presumably be required to carry on the CEEGB's research in this area.

Is it worth risking the negative publicity and threat of class-action litigation in the future that would cloud privatisation plans, or will the electricity industry, in conjunction with the Government, consider it wise to 'green' their respective images and work out some sort of solution to the problem of electromagnetic fields in the environment which many now feel pose a growing and chronic threat to their health? Evidence of electromagnetic bioeffects mounts despite official ambivalence. ■

## VDUs: researchers differ on radiation health risk

Much controversy surrounds the claim that working with VDUs increases the risk of foetal malformation or miscarriage in pregnant women. Claims of increased headaches, tiredness, eye and other problems in operators have been more readily accepted, although alternative suggestions, such as ergonomic problems, tendon strain in the arms and hands, general stress or auto-suggestion, have been put forward to explain operators' claims of health problems associated with the EMFs from VDUs.

VDUs emit various type of radiation, from (ionising) X-rays, almost all of which is absorbed by the glass of the cathode-ray tube, particularly in the later models, and is not considered to pose a hazard, to ultra-violet, infrared, radio-frequency, ELF and static fields. A significant proportion of it consists of pulsed EMFs of between 15-20kHz and pulsed 50Hz fields.

Claims of clusters of miscarriages and other problems began to be reported in the late '70s and have been comprehensively documented<sup>1</sup>, while Pearce<sup>2</sup> has assembled research findings supporting different hypotheses. Some have focussed attention on Levels of airborne chemicals in offices using VDUs, for example PCBs<sup>3</sup>, which were only banned from use as insulating fluids in VDU's in 1986, having been officially recognised as hazardous to health since 1977.

Further research has variously reported an increased incidence of birth defects<sup>4</sup> and abortion<sup>5</sup>, as well as more equivocal results<sup>6</sup>, with criticism being made of aspects of their designs or conclusions.

The TUC recommends that full-time operators spend no more than four hours a day at a VDU, with breaks at

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# RF EQUIPMENT

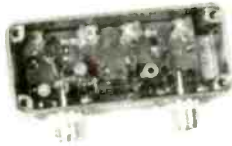
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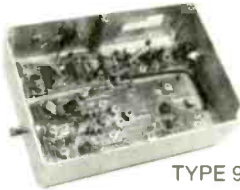


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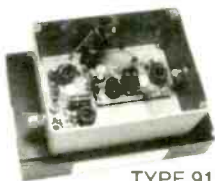
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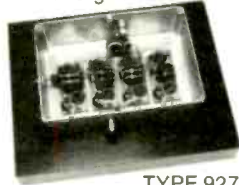
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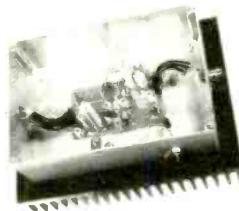
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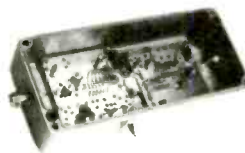
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regular intervals, but the Health and Safety Executive's (HSE) current view is that the emitted radiation poses no hazard to either pregnant or other workers, presuming that one also accepts the relevant NRPB exposure guidelines for the different frequencies emitted.

It bases its reassurance<sup>7</sup> on the fact that 'the very latest research studies have not been able to show a link between miscarriage or birth defect and VDUs.' According to Dr Colin Mackay at the HSE, this view is supported by the results of a recent Canadian study.<sup>8</sup>

The researchers reported no association between VDU exposure and spontaneous abortion risk in a sample of 334 pregnant women matched with both prenatal and postnatal problem-free controls all of whom were administered questionnaires about their VDU exposure over the duration of their pregnancy. Although postnatal controls showed a significant difference in one off or domestic exposure versus the cases, the authors found evidence of differences, possibly due to recall bias, between the reports of the two sets of controls, thus casting doubts on the reliability of some data.

There was a small, non-significant increase in odds ratio for exposures over 20 hours per week (OR=1.07; 95% CI .54-2.11), although only 6.6% of cases (22) were so exposed. No significant trend with increased exposure was demonstrated but the researchers noted that the study "Lacks power to comment on this single stratum of experience."

By contrast, a recent study, not mentioned in the Canadian paper, did find correlations between duration of VDU use and miscarriage and birth defects.<sup>9</sup> Researchers at the health organisation, Kaiser-Permanente, in Oakland, California, found that women who used VDUs more than 20 hours a week during the first trimester of pregnancy had significantly more miscarriages than working women not using VDUs (OR=1.8; 95; CU:1.2-2.8), a risk that could not be explained by age, education, occupation, smoking, alcohol consumption, or other maternal characteristics.

Their study of 1,583 pregnant women showed that the risk of both early (less than 12 weeks) and late (12 weeks or more) miscarriage increased approximately 80 per cent for all women who worked on VDUs for

more than 20 hours a week, compared to those doing similar work without VDUs.

A 100 per cent increase in miscarriage was observed when VDU operators were compared to non-working women. The survey also found a 40 per cent increase in birth defects for both moderate (5-20 hours/week) and heavy (over 20 hours/week) use, against no exposure, but small numbers precluded a statistically significant link. The researchers considered recall bias as a possible explanation but observed that other self-reported exposures, such as to pesticides, were not higher among women with adverse pregnancy outcomes.

The authors also pointed out that the emitted EMFs are in fact at their highest at the sides, rear and tops of VDU terminals – not at the front – and thus that the number of hours at a terminal may not be a reliable indicator of exposure. In fact, it will tend to under-estimate and co-workers' use of machines, so that the risk to pregnancy outcome, if real, is likely to be greater than suggested.

Such a view had previously been endorsed by two Canadian health officials who recommended that VDU



*Damaging: not X-rays but stray magnetic fields from the CRT scanning coils.*

## NON-IONIZING RADIATION

operators should not work within one meter of the sides or back of adjacent VDUs unless the machines have been tested and confirmed to emit only low levels of non-ionising radiation.<sup>10</sup>

### VDUs "environmental health hazard"

Such was the impact of the Kaiser-Permanente study that in the following issue of the prestigious American Journal of Industrial Medicine in which it was published, the editor, Dr Baruch Modan, stated in his editorial that EM radiation 'from computer screens should now be considered an environmental health hazard until proved otherwise', contrary to the HSE's current perception.

Further studies are now in progress in various countries, with the HSE funding one at the London School of Hygiene and Tropical Medicine by Drs Valerie Beral and Eve Roman, which will also consider electric blanket use and whose results are due shortly. A study by Bramwell at UMIST is also due to report soon<sup>11</sup>.

Currently, there is an EEC Directive proposal<sup>12</sup> that will require member states to pass laws covering the operation of VDUs, possibly to include mandatory eye tests, by no later than January 1991, which has led to a debate in the House of Lords over Britain's response and compliance<sup>13</sup>.

For those concerned to minimise the EMFs emitted by a VDU, a number of companies now produce low-magnetic-

field screens, as well as special shields (which will only restrict certain frequencies), while IBM has just patented a technique to reduce the magnetic field inside a VDU by 10-fold, down to 200nT. Here, the British Standards Institution is in the process of issuing new standards for VDU design, although these will not cover radiation.

However, these are somewhat ad hoc measures given that they still rely on the conventional cathode ray tube (CRT) and fly-back transformer, which generates pulsed, saw-toothed magnetic fields. It is these pulsed fields that have caused perhaps the most concern, exposure to similar fields having been linked in some studies to abnormalities in mice and chick embryos.<sup>14</sup>

### LCD screens

For those wishing to avoid generating such fields altogether, the latest state-of-the-art screens are liquid crystal display (LCD), whose technology has improved considerably over the past five years. Although still not quite up to the standard of CRT-system screens, they nonetheless dispense with the latter's associated fields (producing only relatively weak fields) and, though currently more expensive, will fall in price as demand increases. Driven by the technology of video-phones and video-conferencing, LCD screens may well dominate the market within 10 years.

A pressure group, the VDU Workers' Rights Campaign, was set up in

1985 and monitors latest research as well as holding conferences and publishing information. It recently published the results of a survey of 192 VDU workers which, among many statistics, found that 94% experienced four or more symptoms of ill-health sometimes or often.<sup>15</sup>

One of the main aims of the campaign is to get legislation to give pregnant women and those attempting to become pregnant the right to transfer to alternative work, based on the proposition that women should not have to wait for conclusive proof that VDUs pose reproductive hazards before steps are taken to prevent the possible risk.

While the evidence may not be conclusive, the answer is also far from being the cut and dried case the HSE might have one believe. ■



Safe, expensive, CRT replacement: the LCD alternative.

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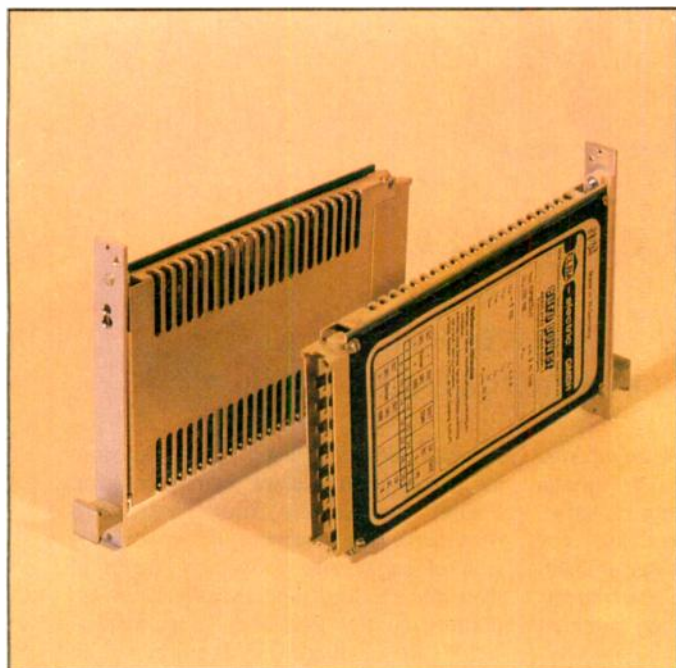


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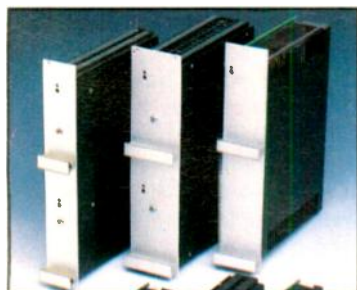
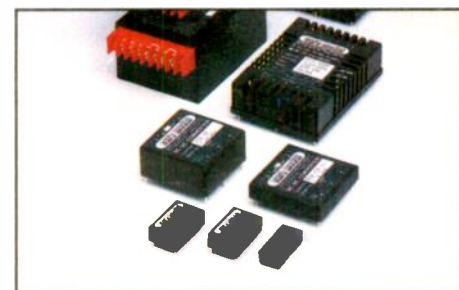
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# KILLING FIELDS

## The Biophysical evidence

Roger Coghill examines the cellular evidence pointing to the hazardous effects of non-ionizing electromagnetic fields

**T**HE impact of non-ionizing electromagnetic fields (NI-EMFs), both on organic cells and whole live animals (including man), has been the subject of increasing scientific curiosity during recent decades. This is partly because of the rapidly increasing use of such energy (for the first time this century) in heating, lighting and telecommunications, and partly because it helps throw light on major unsolved biological problems such as morphology (the structure and form of organisms), the initiation of DNA uncoiling, immune defence, and the regulation of cell division (meiosis and mitosis).

Despite advances, we still do not know what controls the organic cell cycle in any multicellular creature. Every day the average adult loses some 500 million cells; every night nearly 90% of these are replaced through a highly specific process of cell division, as the requisite cells mysteriously split into two by mitosis, thus repairing and maintaining our bodies' shape. Were it not for this, we would soon lose our familiar appearance, from face to fingerprints, and within a year perhaps be unrecognisable.

It is impossible that the necessary central commands of the system are passed down 'hard-wired' neural pathways from the brain, even if the nerve fibres reached to every cell, which they do not. Given the average speed of nervous conduction at 40m/s, it would take some 350 hours to deliver the coded instructions for mitosis and protein synthesis, which are somehow accomplished in about five separate periods, totalling a mere 120 minutes each night.

The science of immunology was born only in the 1960s. Its students realise that there is a complex system of recognition

within us, capable of distinguishing between our own cells and foreign invaders or damage, whether ablative, toxic or organic, and repelling any invaders by a variety of mechanisms still little understood. Here, too, experiments with EM fields throw light on some of these mysteries.

With the application of ionizing radiation in our world, for medical purposes (X-rays), through energy production (nuclear power stations), to war (atom bombs), has come acceptance that this part of the electromagnetic spectrum at any rate is hazardous, and can produce mutations. The history of ionizing exposure limits has been in consequence one of continuously falling values, from 10 rems\* per day in 1900 to 5 rems per year in 1957, with further modification likely.

We can begin to say with some certainty that the body's mysterious controlling influences are also interfered with when cells are exposed to NI-EMFs, even of very low intensity, but the effects are puzzling and no clear pattern has yet emerged to explain them consistently. As Szent-Gyorgyi, the Nobel prizewinning physician and biochemist who discovered vitamin C once said, "It looks as if some basic fact about life is still missing, without which any real understanding is impossible".

Without any such master plan, the sporadic results of research to date are like pieces of a jigsaw for which there is no box nor even any outline.

Such facts which emerge are often, in consequence, almost equally confusing.

*\*röntgen equivalent man. Unit of biological dose given by the product of the absorbed dose in rads and the relative biological efficiency of the radiation.*

For example, a single ten-minute exposure at 25microwatts/square centimetre and 10GHz (wavelength 3cm) produced a decrease in the phosphorylation (conversion of sugar into phosphate) factor in liver mitochondria, and an increase in respiratory control in kidney mitochondria. Yet a single exposure at 100microwatts/square centimetre had the reverse effect and, after ten such exposures, the indices all returned to normal as if the cells had made compensating adjustments for the insult (Sivorinovskiy; Reisen *et al.*<sup>2</sup>). In such studies, yes there are effects, but what do they mean?

### Initial Confusion

The triglyceride story is another example of just how confusing experimental results can be. Back in 1973, Dr Deitrich Beischer at the Naval Aerospace Medical Research Lab. at Pensacola confined several sets of up to three USAF officer dropouts in a room 2.4 x 4.8m (including a bathroom area 1.2 x 2.4m) for periods up to a week, during which time they were exposed for up to one day to magnetic fields of about 10<sup>4</sup>T at 45Hz much higher than one would find under an average power line. The subjects' serum triglyceride levels were found after this period to rise and, since triglycerides are an accepted warning of potential heart problems, the finding initially caused some concern<sup>1</sup>.

That December, the Navy embarked on similar tests with animals. But applying the same field to rhesus monkeys (Delorge<sup>4</sup>) produced the reverse effect: a significant but unrepeated decrease was found. And when Beischer himself tried the same thing out on mice in 1974, the results were also negative<sup>5</sup>, as were the results of exposing human beings to weak

ELF magnetic fields (Krumpe and Tockman<sup>6</sup>; Houk<sup>6</sup>).

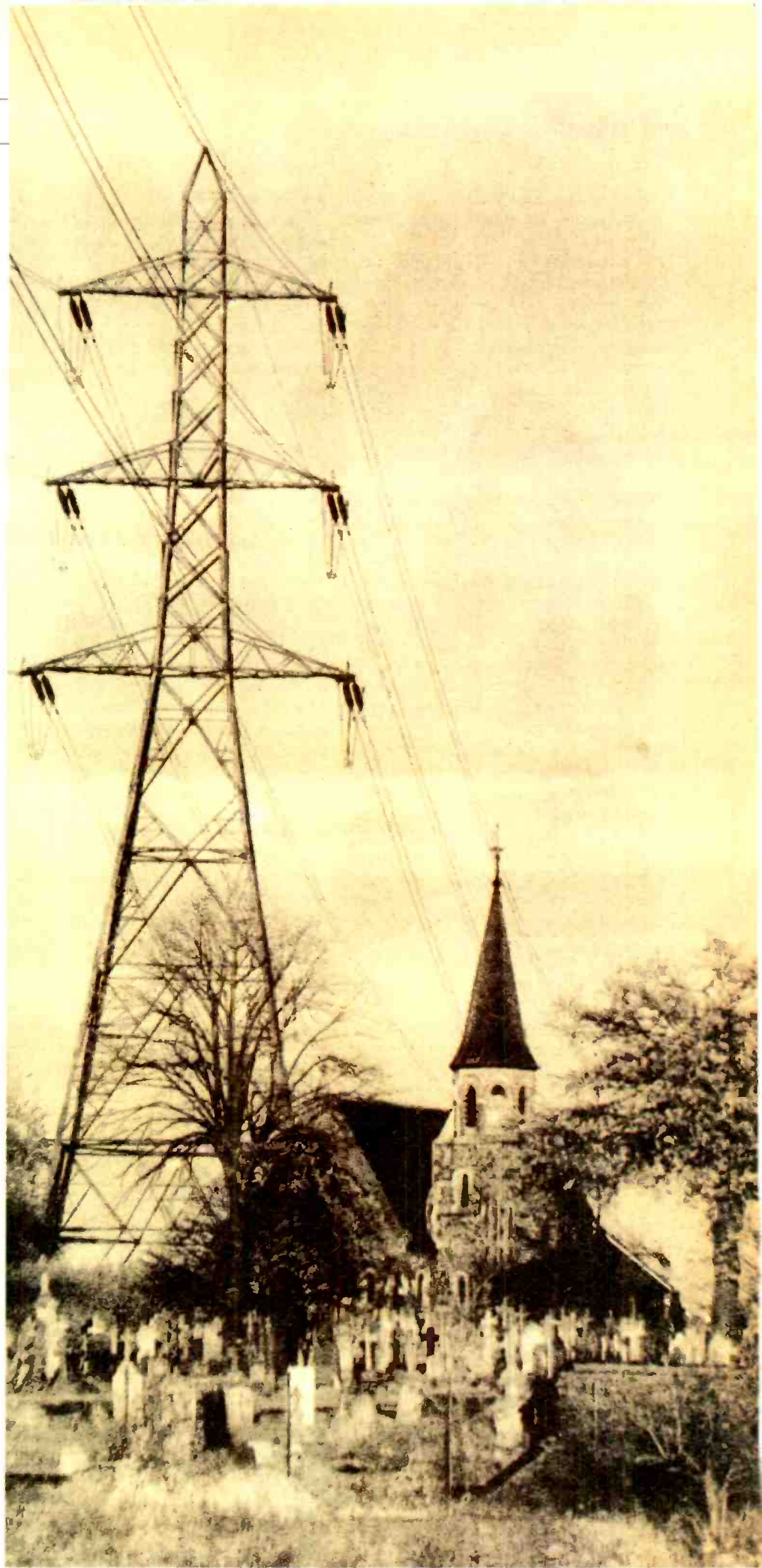
Even when the field strengths were increased to  $3 \times 10^{-4} \text{T}$  and  $20 \text{kV/m}$ , "pathological changes could not be found for the measurements of serum triglyceride and of cholesterol levels which could be traced to the influence of electric and magnetic AC fields. The influence of triglyceride, described by Beischer for example, could not be observed."

Though Smith and Best<sup>8</sup> say that a 1980 review by Grissett<sup>9</sup> (Beischer's former colleague) omits any reference to Beischer's work, implying that skulduggery was afoot, it was in fact extensively reviewed by Bridges and Preache in their 1981 overview of the biological effects of power frequency fields for the IEEE, and the problems pointed out<sup>10</sup>. One might suppose that if you imprison a few young naval officer dropouts in a small room for a week with nothing much to do, they might start to put on fatty tissue from an uncontrolled diet, or even start arguing and fighting among themselves to use up some of their energy, which is what happened. As Beischer himself recorded at the time: "No effects were seen which could definitely be linked with the magnetic field. However, serum triglycerides in most subjects appear to be affected by some factor, or combination of factors, associated with the experimental protocol. The number of subjects is too small, however, to include statistically other factors such as psycho-physiological reactions to forced changes in personal living habits, modified activities, restrictive diet and confinement". I personally doubt that any great cover-up was going on, or that Beischer's initial unreplicated findings were unduly sinister.

### Sensitive Lymphocytes

The impact of magnetic fields on the immune system (arguably a more important field of study) is fortunately more consistent, or at least follows a repeatable pattern. In 1983 an Italian team (Conti, Gigante, *et al.*<sup>11</sup>) found that challenging the human peripheral blood lymphocytes with antigens like pokeweed mitogen and concavalin-A in the presence of fields of 0.0023 to 0.006T, pulsed at 1 to 200Hz, seriously affected their mitogenesis (that is their ability to divide).

Curiously, it was the frequency at which they were bombarded which made all the difference: pokeweed mitogen was only inhibited at 3Hz, another mitogen at only at 200Hz, and at 50Hz the pokeweed mitogenesis was not induced at all. Clearly, some sort of frequency dependence is associated with specificity of mitogenic response in the immune



## NON-IONIZING RADIATION

response of lymphocytes. Have we found a radio transmission mechanism in biology?

In a separate lab. in California Dan Lyle, Schechter, and colleagues from Loma Linda, working under the supervision of Ross Adey, found in 1983 that microwave irradiation at non-thermal levels could also interfere with lymphocytes' ability to identify invading cells<sup>12</sup>. Using a cultured T-lymphocyte cell line developed from mice (CTLL-1) they exposed them to cancer cells, which the T-cells would mark for destruction. But when they did the same test while the T-cells were being irradiated by microwaves at 450MHz (the frequency used in America's new phased-array early-warning system, PAVE-PAWS) pulsed at 60Hz, the T-cells' ability to kill the cancer cells was markedly inhibited. Later (in 1988) they found the same thing with power frequencies<sup>13</sup>: the lymphocytes' abilities fell by up to 25% in the presence of an electromagnetic field, evidence perhaps that this 'radio interference' was disrupting normal operations in some way. Paul Brodeur refers to Lyle's work in a series of New Yorker articles<sup>14</sup>. Though critics have attacked some other parts of his piece, which caused a good deal of interest at the time, detractors have remained ominously silent about these immune system effects.

The work of Lenzi way back in the 1930s, Webb in the 1940s, and of Madeleine and J.M. Barnothy in the 1940s and 1950s on whole animals had already found similar effects. In 1939, Mario Lenzi, a radiobiologist from The Regia University at Modena, Italy, reported to

the fifth Italian Congress of Radiobiology at Turin what he called modestly "a few recent experiments on the biological effects of magnetic fields"<sup>15</sup>.

"In animals placed in an alternating magnetic field at 42 cycles per second for eight hours a day", he reported, "the 'taking' of a tumour graft was delayed to the highest degree, so that on the twelfth day, while the controls showed 92 out of 100 positive results, these only showed 25 out of 100".

S.J. Webb was more interested in the action of microwaves. With a colleague A.D. Booth in 1969 he reported to Nature<sup>16</sup> that at specific frequencies cell growth was significantly retarded, and that temperature changes didn't seem to play a part in the effect. Thus three frequencies (66, 71, and 73GHz) were found to slow the growth of cells, whereas 68GHz microwaves stimulated it.

Madeleine Barnothy, from the College of Pharmacy at Illinois, was following up some early post-war work by J.M. Barnothy which found that, if mice were placed in magnetic fields their cell division (mitosis) was generally retarded. The life-span of leucocyte in the blood is short, of the order of one day, she pointed out. Should the magnetic field affect the leucocyte-producing organs, the leucocyte number would change and provide a suitable test of mitotic activity. In following up her notion she accidentally reproduced leukemic conditions in her subjects: applying a vertical magnetic field did decrease the number of circulating leucocyte by up to 40%, but had no effect on the red blood cells, which have no

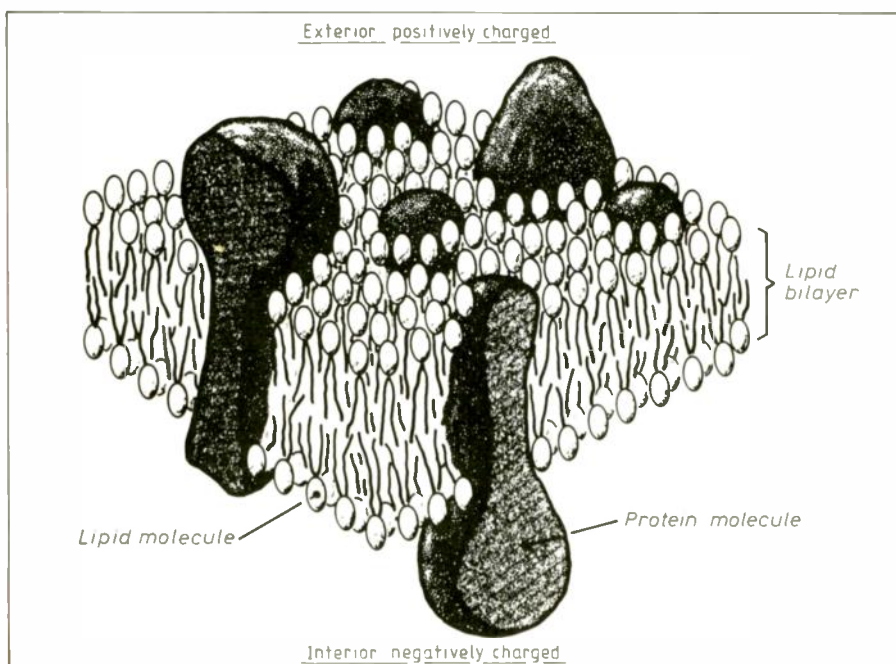
nucleus<sup>17</sup>. However, after removal of the powerful (334 000At m<sup>-1</sup>) magnetic field, a recovery set in, during which the leucocyte count overshot the baseline by 20%, a fact confirmed by several other experiments.

### Immune Deficiency

Bob Liburdy, a genial, beefy Marcello Mastroianni look-alike from the Radiation Sciences Division, USAF School of Aerospace Medicine at Texas, has been looking at the same problem from the higher radio-frequency point of view for over a decade. In 1979 he published a paper in "Rad Res", the most important scientific journal for radiation scientists, which proved that radio frequencies can alter the immune system, at least at levels which slightly raise the temperature<sup>18</sup>. He also used mice, which he irradiated at 26MHz at 800mW/cm<sup>2</sup> for fifteen minutes. This had the effect of increasing their core temperature by two degrees Celsius. It also induced acute transient lymphopenia, that is to say loss of the vital lymphocytes which alone stand between us and infection. He then noticed what Madeleine Barnothy had seen: there was a subsequent relative increase in splenic T- and B- lymphocytes and, moreover, these elevated levels were further pronounced when further RF radiation exposures were given at three-hourly intervals. But if the mice were warmed simply by applying hot air to achieve the same temperature rise, there was no effect on the mouse T-cells. The vital question is, what effect does non-thermal long-term exposure to radio-frequency radiation have on our immune systems? Liburdy's tests were not in the test tube, they were in vivo: but do mice react the same as human beings might?

The disturbing thing about Lyle's field strengths (they were at 60Hz, the frequency of the domestic US electricity supply) was that they were only at about 0.1 to 1.0mV/cm (equivalent to 0.01 to 0.1V/m) which is well below the permitted exposure limits currently in force and might be found in any ordinary home.

"Our report," argued Lyle, "based on in vitro assays, naturally leads to the question of whether 60Hz sinusoidal fields in tissue might inhibit the cytotoxic (cell-destroying) T-lymphocyte immune defence mechanism, lessening growth restriction for antigenic tumours. .. Caution is counselled, however, because several factors affect this interpretation: 1) reduced cytotoxicity has so far been seen only in an in vitro preparation; 2) mouse, rather than human cells were studied; 3) our observations involve only one clone of cytotoxic T-lymphocytes."



**Section of cell membrane. EM fields cause calcium loss and collapse of the protein molecules leading to breakdown of the cell membrane.**

"Electric fields", he adds, "in the range of 0.1mV/cm can be induced in humans in close proximity to some high-voltage power lines (Kaune and Phillips<sup>19</sup>). The role of electric fields as a factor or co-factor is not clear. Also, development of cancer is generally a long, chronic and complex process, which generally occurs over a 10-30 year period after initial cell mutations. If subtle insults to the immune system by chronic exposure to appropriate fields were cumulative, field strengths needed for a significant long-term inhibition of specific cells might be less than those observed in the short-term assays described here."

Lyle's results have since been replicated by others all round the world, but of course events in the test tube are not the same as events in the live body. So are there any equally conclusive results, and is the immune competence of whole live animals also affected by magnetic-field exposure at those minuscule levels?

One recent Chinese study was reported in the *Journal of Bioelectricity* in 1989<sup>20</sup>), whose editor, Andy Marino, was also responsible for a collection of papers which covers most of the recent research work, particularly from the eastern bloc<sup>21</sup>.

The Chinese report, a multi-faculty study headed by H. Chiang and G.D. Yao, from the Microwave Institute of Zhejiang Medical University, is nothing if not laconic.

"We investigated the effects of exposure to environmental magnetic fields in 1170 subjects. Neutrophil phagocytosis was enhanced in low-intensity exposure groups, but reduced significantly at relatively high intensities. Visual reaction time was prolonged, and the scores of short-term memory tests were lower in some high-intensity exposure groups. (NI)EMFs may affect the central nervous and immune systems in man". Thus runs their abstract.

A closer look shows that, by low-intensity, they meant 0.4  $\mu\text{W}/\text{cm}^2$  while by high levels were meant 13-42  $\mu\text{W}/\text{cm}^2$  — both being well below the official US limits. The subjects were living and working near radio antennae and radar installations.

The WBC phagocytosis (ingestion of foreign cells) index showed a progressive fall with intensity, whether exposure to microwaves or AM radio was invoked:

exposure to microwaves:	
0.4 $\mu\text{W}/\text{cm}^2$ (boys)	123.0
0.4 $\mu\text{W}/\text{cm}^2$ (girls)	115.8
10-15 $\mu\text{W}/\text{cm}^2$ (soldiers)	99.3
13-42 $\mu\text{W}/\text{cm}^2$ (students)	87.2
exposure to AM radio:	
3-4 V/m (children)	115.3
4-11 V/m (children)	131.2

10-18 V/m (boys)	89.8
10-18V/m (girls)	78.7
22-23 V/m (boys)	45.7
22-23 V/m (girls)	81.2
Significance was between P<0.05 and <0.01.	

The researchers quote a Russian study Solokov<sup>22</sup> in support of their findings and say "the test (of response time) is limited due to the influence of cultural levels, subjective moods, consciousness, and other environmental factors of the subjects. In contrast, the WBC phagocytosis is an objective index of non-specific immune function".

Marino's collection (*Modern Bioelectricity*, 1988) includes a review of immunologic studies by Stanislaw Szmigielsky from Poland<sup>23</sup>. It was his research into the effects of radar on Polish servicemen which caused something of a shock in epidemiological circles, by reporting that, in a large-scale survey, radar servicemen were seven times as likely to suffer immune deficits and carcinogenic conditions.

Among many eastern bloc studies he relates one particularly appropriate to our problems in the West with salmonella. "In earlier experiments Russian investigators found a reduction of circulating antibodies to salmonella in mice, rabbits, and guinea pigs immunized following several months of exposures to 10GHz microwaves at 10mW/cm<sup>2</sup>. Unfortunately, the conditions of irradiation, time of daily sessions and even the period of exposure were not described".

The study he referred to by Jakovleva<sup>24</sup> was performed in 1973, well before the current spate of salmonella enteritises outbreaks among the chicken and human communities. When one considers that battery hen production involves twenty-four-hour irradiation of the hen and egg alike by power-frequency light and heat, Jakovleva's results may well have been unwittingly replicated by our own farmers.

Most of the acceptable information on immunological responses to low-level long-term exposure of experimental animals to microwave/RF radiations has come, however, from investigations during the last decade. Szmigielsky cites four or five such studies, concluding that "There are no experiments in vivo involving exposure of animals to low-frequency modulated microwaves with examination of the immune function. On the other hand... both the higher susceptibility of animals to chronically exposed bacterial and viral diseases, and the data on the acceleration of development of tumours in mice exposed for months in non-thermal fields (the two phenomena that might

result from suppression of immune functions in chronically exposed subjects) emphasize the problem of the response to long-term irradiation in microwave/RF fields, and they call for further investigation".

## Disrupting DNA

As well as helping to determine whether NI-EMFs affect human beings deleteriously, such experiments also throw light on life's deepest processes, and in particular begin to suggest that multicellular animals actually use some form of electromagnetic communication system to maintain their form.

"It is not known what actually triggers the initiation of DNA synthesis," admit Alberts, Bray and the team who developed a recent massive textbook on cellular biology<sup>25</sup>. (The team includes the famous Jim Watson, who with Francis Crick and a London University team first described the structure of DNA in the 1950s.) "Nor whether the S-phase of DNA synthesis begins with a sudden replication of DNA at many sites on the genome (*complete DNA code of an animal*) or more gradually ... Whatever the details, the triggering mechanism is clearly of the all-or-none type, since once the S-phase (*synthesis*) is begun, DNA replication will continue until all of the cell's DNA is replicated".

Watching the 150 million linked nucleotides in a human chromosome start to uncoil, as if in response to a mysterious signal, and with a startling speed spill out from the tight coils of its chromosome, is a breathtaking sight only rivalled by that other fascinating balletic act, cell mitosis itself. The spilled nucleotides of DNA from a single chromosome seen through an electron microscope would fill an A3 page with tight, fine lines of thread.

For over a decade Reba Goodman, who is always ready to listen to critics of her careful experiments, has been tirelessly investigating the effect of EM fields on DNA and RNA transcription. In 1989 she presented three papers at the Bioelectromagnetics Society's annual meeting at Tucson, where the cream of research scientists active in this field had gathered to exchange information and communicate their research progress<sup>26</sup>.

She showed that by exposing cells for a short time to ELF (extra low frequency) NI-EMFs, the quantity of RNA transcripts can be altered<sup>27</sup>. Again, the power densities and amplitudes used were minute: 1 $\mu\text{V}$  to 1mV. Why and how do these electromagnetic signals turn on and off the very processes of life? Reba and her team at Columbia University have shown that transcription and translation of DNA switches are frequency dependent.

Meanwhile an Austrian researcher, Fritz-Albert Popp, has turned the problem on its head and discovered that cells themselves give off ultra-weak photon emissions. Using cucumber cells, he found that just prior to cell-death they emit the electromagnetic equivalent of a flash of light<sup>28</sup>. Are the dying cells communicating the fact of their demise by minimum-power radio-telemetry to some distant receiving site?

Ross Adey and his team at Loma Linda V.A. Hospital have been addressing this enigma for nearly twenty years. His solution is that organic cells, using the minute potential difference which acts as an electrical barrier for the plasma membrane, can signal to each other at a local level. The purpose of these signals is unclear, but one certain fact seems to be emerging: the imposition or interference of any NI-EMF signal — particularly if it is modulated at the same kind of frequencies as are detected in EEG records (10-25Hz), has an inhibiting or sometimes proliferating effect on cell performance, including the vital activity of cell division and protein synthesis.

As Reba Goodman points out, an analysis of the specific cellular responses to NI-EMFs, based on an electrochemical model that has successfully described the opening/closing reactions of voltage-gated channels in a cell's plasma membrane and the ion flows during nerve excitation (Blank, BBA, 906: 227 (1987)), predicts that the charged surfaces involved in biosynthesis should experience frequency-dependent interference in alternating EM fields.

Ross Adey, William Fletcher and their team used the newly emerging technique of fluorescent-dye migration to see what happened to cell-to-cell communication when phosphorylation is interfered with by protein kinase (effectively enzyme activators)<sup>29</sup>. They found that when a cell was injected with a fluorescent dye (Lucifer Yellow), the dye moved to all contacting cells, and beyond them to cells in 3rd and 4th-order contact within two minutes. If a cell was given the protein kinase inhibitor first, however, the dye did not transfer to other cells. The same effect could be achieved with the help of a modulated microwave field.

In 1988 at Dublin's Mater Misericordia Hospital, Darragh Foley-Nolan and his small team were investigating small-cell carcinoma of the lung, a rapidly proliferating malignancy almost always fatal. Current chemotherapeutic treatment does not work. However, in three groups of five separate experiments they exposed the malignant cell line continuously to an RF field, pulsed at 27.1Hz, of maximum

**“...Ross Adey saw a tell-tale efflux of positively charged calcium from cells they had exposed in this way.”**

power density 3mW/cm<sup>2</sup>, and found that proliferation of the malignant cells was significantly inhibited by the RF field<sup>30</sup>. A similar result with human mononuclear cells was obtained by Stephen Cleary at Virginia's Commonwealth University, Richmond<sup>31</sup>. In this case they used 2450MHz CW (the frequency of all microwave ovens) or pulse-modulated RF. When they examined the cells after one, three and five days, they found that there had been a highly significant degree of dose and time-dependent modulation of cell mitogenesis, when stimulated by a another mitogen.

## Cellular Breakdown

Of course, intense electric and magnetic fields have long been known to cause biological effects, both via heat production and by the triggering of nerve cells. The search for the mechanism whereby such effects are also observed as a result of low-intensity fields continues, with a variety of mechanisms and models offered. Currently interest is centred on cell membranes and the transport of signals across them, and on cyclotron resonance.

Slowly the picture is becoming clear. For example, we know that the cell membrane presents a formidable electric barrier. Though the potential difference between the interior (negatively charged) and the exterior (positively charged) is only, say, 100mV, since the membrane itself is only a mere 5nm thick, this represents a field strength of 0.1V/(5 x 10<sup>-9</sup>) V/m, which is a staggering 20MV/m, protecting the interior of the cell — cytoplasm and nucleus — from any ordinary changes in electromagnetic energy.

Inside the cell there are microtubular structures, - actin and myosin microfilaments which hold each eukaryotic cell (a cell with a highly organised nucleus) in

place, - a kind of microbiological scaffolding. These scaffolding poles are absent or virtually absent in cancer cells<sup>32</sup>. The ways such structures are created is by polymerising chains which use calcium for stiffness: the actin/myosin filament attaches its negative end to a binding site on the cell's nucleus wall and starts to grow outward, mainly at the positively charged end, towards the negatively charged interior of the plasma membrane.

This is fine so long as the interior of the plasma membrane stays negatively charged, because opposite polarities attract. What happens when the cell membrane is exposed to any alternating EM field is still a mystery, but in 1976 Susan Bawin and Ross Adey saw a tell-tale efflux of positively-charged calcium from cells they had exposed in this way<sup>33</sup>. Were the microtubules breaking down, leaving a surfeit of calcium inside the cell, which was then expelled? Without their vital supplies of calcium the cells subsequently risked becoming neoplastic, or cancerous. In following up this mysterious efflux of calcium from brain tissue cells, Ross Adey found that threads of protein from the cell walls can sense weak electric fields and transmit them to the inside of the cell; a cellular aerial of a sort. (Viruses seem to have similar protrusions which may act as sensors.) Adey also found that these “aerials” can only receive frequencies below around 100Hz. This implies that intercellular signals, if carried by high-frequency carriers, must be coherent.

At Leeds University, Herbert Frohlich has long argued that coherent signals can be amplified enormously by cells and nerve fibres, and only in this way is it possible to explain how the human eye has been proved sensitive and capable of detecting a single photon of light. The energy necessary to convey that message must come from within the cell itself, claims Frohlich<sup>34</sup>.

If so, then the proponents of the view that only thermal levels of EM energy can have a biological effect will have to think again. Frohlich points out (quoting Bullock, 1977) that certain fish are sensitive to an EM field as low as 10-8V/cm.<sup>35</sup>

As if anticipating the central nature of morphogenetic control (the way in which our shape is organised) and the frequency bands within which it is organised, Frohlich points out that “In recent years it has been found that electric fields at very low intensities in the region of 10-20Hz, as well as in the microwave region, appropriately modulated, can severely influence the electroencephalogram, as well as calcium efflux and other brain activities (as discussed by Adey and Bawin, 1977<sup>36</sup>). It was also reported by Raphael Elul<sup>37</sup> in

1974 that during certain periods large regions of the brain oscillate coherently".

Certainly the human brain is organised spatially so that the highest and strongest inter-hemispherical action potentials are located in those areas of the cortex where motor and sensory activity is concerned with the body's most distant components. Wilder Penfield and Karl Lashley found this out in the 1930s<sup>38,39</sup>. Not long before then, Hans Berger had discovered oscillations from the brain at 10Hz<sup>40</sup>, and Cazamalli claimed to have detected very much higher frequencies<sup>41</sup>. Though it was soon realised that these rhythms change with illness<sup>42</sup> and in sleep, their significance is still largely a mystery.

Without actually saying so, all these specialist researchers into the bio-effects of EM energy are being forced to admit (a) that cells intercommunicate coherently and (b) that artificial EM fields interfere with that communication system.

It is understandable that the myriad separate cells which comprise any multicellular organism are co-ordinated centrally; indeed, if it had not been postulated one would have had to identify some similar mechanism. The backbone of any such co-ordinating system, moreover, would have to embody a code or flag of some sort unique to that individual collection of cells. The DNA macromolecule, - unique, as police pathologists now know, to every single creature, - has to be that code.

If cellular biology points the way to EM signalling from the test tube and petri dish, the very same message is emerging from live animal studies. Most protein synthesis, as Haider and Oswald showed<sup>43</sup>, occurs during sleep, and particularly that kind of sleep known as 'paradoxical sleep'. It is called paradoxical because sleep scientists could not understand why, when the body was so inert and "dead to the world", the brain was at its most active, emitting energetic, desynchronized and agitated EEG signals. Could it be that the brain itself was communicating instructions for the mitosis and protein synthesis which took place at such times?

## EMFs and Cot Deaths

Before one can examine such speculations it is important to imagine what happens to living animals chronically exposed to EM fields. Hans Arne Hanssen of Gothenburg has devoted most of the 1980s to such studies. His classic experiment placed two groups of young mammals from the same litters underneath high-voltage power lines, one group being protected by a Faraday cage. After several months the animals were killed and subsequent necropsy showed that the exposed



*Low voltage, high current cable runs can induce large fields at bedroom height.*

group, unlike the controls, had suffered minute lesions of cerebellar Purkinje cells<sup>44</sup>.

In 1976 Gadsdon and Emery examined the post-mortal brains of over one hundred human infants who had been the victims of sudden infant death syndrome or cot death<sup>45</sup>. They found similar damage in the majority of cases: sudden loss of the fatty sheath of the corpus callosum (the connection between the cortical layers of the two lobes of the cerebellum) had led to coagulation of its fatty tissue round the blood vessels of the lateral ventricles.

One study by Eckert in the same year<sup>46</sup> had pointed out that in Hamburg, West Germany and Philadelphia in the USA, two separate reports indicated that cot deaths seemed clustered near electric railways. Following up these studies I too found that at the actual cot locations of SIDS victims, electric field strengths were at least four times normal domestic levels, without exception. Could this be evidence that the neonatal brain's transmission system had overloaded in trying to compete with an interfering signal?

The preliminary evidence I found deserves further investigation. Often the source was obvious; for example, an infant would characteristically sleep in the parental bedroom for the first few weeks after return from the maternity hospital, during which time it would grow normally. Meanwhile, a nursery room might typically be prepared, and quite naturally the parents would choose one which was

**"...at the actual cot locations of SIDS victims, electric field strengths were at least four times normal domestic levels without exception"**

warm, next to the domestic hot-water tank with its immersion heater, for example. Several weeks after transferring the infant to the new location it would unexpectedly be found dead, with the only prior indication a few snuffles, suggestive of minor immune damage<sup>47</sup>.

\*Measuring the fields in the new cot location, I would typically find electric field levels of around 70V/m, evidently as a result of proximity to the hot-water immersion heater; turning off the electricity at the mains would collapse this field completely.

A study by two US researchers, Barnes and Wachtel<sup>48</sup>, this year established that the average electric field in a typical home is only about 10V/m. So the cot-death infants had been chronically exposed to fields many times the norm prior to death. There are sporadic reports in the literature

unwittingly linking cot death to electric fields: one study from Scandinavia reported that six out of thirty-four cases had occurred in beds heated by electric blankets or electrically heated water beds<sup>49</sup>. Another case was reported in the *Lancet* of an infant found unexpectedly dead after being put in a carrying cot on a floor heated by underfloor electrical heating. In both reports the researchers had linked the deaths simply to overheating.

A little-reported study by Nancy Wertheimer also adds weight to the possibility<sup>50</sup>: she found that foetal loss among mothers in Eugene, Oregon, occurred more frequently in homes heated by ceiling electric cables, and during the winter months. Since amniotic fluid maintains foetal temperature at exactly that of the mother, the idea of overheating in those cases can be eliminated. Ceiling-cable heating is essentially like a big electric blanket that has been installed in the ceiling, points out Paul Brodeur, so current flowing at the outer edges of the cable pattern is unbalanced, just as it is in electric blankets. As a result strong electric and magnetic fields are generated.

Animals seem sensitive to electric fields, both natural and artificially generated, and try to evade them: the rat is a highly intelligent and fast-reacting creature, sensitive to colour, sound and smell beyond the capability of human beings. In one experimental study it was found that they can also be sensitive to EM fields and can be retrained to avoid them, even removing their young and recreating their nests in unexposed areas of the cage. Even bees, it is found, block up their hives in the chronic presence of NI-EMFs. ■

## Microwave irradiation studies suggest need for lower limits

The UK allows microwave exposure orders of magnitude greater than those existing in Russia and the US, and at levels which have definitely been associated with pathogenic effects.

Considerable concern has been shown in the five deaths that have occurred at the Royal Signals Research Establishment at Malvern, all from brain tumours, giving an incidence rate 6.4 times the national average. The MoD has not indicated what, if any, research it is doing on RF/MW irradiation.

US studies of incidental civilian exposure from airport radars indicate a similar cause for concern. One residential building within line-of-sight exposure from radars at two airfields had a cancer morbidity of six times an unexposed control group.

These cases represent some of the more sensational instances of a suggested link between microwaves and disease. However, they are supported by a number of solid epidemiological studies into the linkage. The results of the studies will be examined in detail in the next issue of *Electronics World + Wireless World*.

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# KILLING FIELDS

## THE POLITICS

Alasdair Philips looks beyond the figures to find out why official bodies seem unimpressed by the weight of evidence

**T**HE previous articles have given an overview of the state of our published knowledge regarding possible health effects of alternating electric and magnetic fields at low levels.

We have examined the latest National Radiological Protection Board (NRPB) GS11 guidelines and find it interesting that "there are at present no specific regulations in the United Kingdom governing the exposure of either workers or members of the public to electromagnetic fields at frequencies below 300GHz".

The guidelines continue: "There does appear to be evidence for athermal biological effects, particularly of magnetic fields, at all levels of biological organization. However, the experimental evidence is often statistically weak and proves difficult to reproduce. It is not possible to say either with certainty or quantitatively whether this evidence has any implications for human health".

It is interesting to note that, although the 1986 discussion document published by the NRPB suggested a limit for continuous exposure to 50Hz magnetic fields of  $174\mu\text{T}$  and the new 1989 IRPA/INIRC limit is  $100\mu\text{T}$ , the NRPB 1989 Guidelines has raised this to  $2\text{mT}$ . In other words, the international guideline is twenty times lower than the new UK one. No explanation is given for this change of view.

In the UK, the responsibility for set-

ting exposure levels rests with the Health and Safety Executive (HSE) who base these on scientific advice from the NRPB. They, in turn, take considerable notice of advice from the Medical Research Council (MRC) which comes, it seems, largely from a group of scientists who have done little or no research in this area.

The guidelines conclude: "The Board regards it as important that basic research and epidemiological studies are continued to determine whether the risks are real and, if so, their underlying causality. The Board will issue further advice as the results and conclusions of such research and studies become available, and intends to publish a review of the existing biological and epidemiological evidence in the near future". The report was approved in November 1988.

Much of the work we have looked at has been done by respected scientists, and yet from the many hundreds of research reports available, the NRPB chose to list virtually none in their list of 38 references. This list consists mainly of lists of other 'official' bodies' reports, most of which are as conservative and non-committal as the NRPB report. In fact, it is difficult not to conclude that most of the reports showing possible dangers from low-level non-thermal effects of EM fields had been deliberately excluded. The NRPB has still not published its promised literature review.



## NON-IONIZING RADIATION

At present, there are no EEC-funded projects studying non-ionizing radiation, nor any joint EEC proposals on exposure guidelines.

Work in these areas is often funded directly or indirectly by the military or large firms with vested interests. Controversial work is often classified or just stopped. In fact much of the informative work that has been done over the last 15 years has been done personally by the researchers in their own time and with their own money. It is hardly surprising, then, that official bodies can voice the criticism that the work hasn't been done on a sufficient scale with sufficient controls. Let us consider some specific examples.

In 1964, Dr Milton Zaret was one of the first scientists to speak out about the dangers of microwave radiation and ocular effects. According to Zaret, exposure to either thermal or non-thermal radiation can cause cataracts, which can remain latent for months or years. Zaret then had his laboratory research funds cut off. "Now that's a very strong signal to everybody else in the field" says Zaret in the 1984 Central TV documentary "The Good, the Bad, and the Indefensible" (GBI, 1984).

In 1973 Dr Deitrich Beischer was investigating the pulsed ELF from the Sanguine submarine communication transmitter for the US Navy at the Clam Lake, Wisconsin, site. When Beischer tried to talk to other US official bodies about this work, he was removed from his post as a research team leader at the US Navy's Pensacola Research Labs and his previously unclassified work was subsequently classified. Dr Beischer had been one of the US Navy's principal investigators since the late 1940s.

### COINCIDENCE

One of the people he tried to talk to was Dr Robert Becker, who had been nominated twice for a Nobel Prize for his work on healing bone fractures and oedemas with externally applied ELF electromagnetic fields. At the time, Becker had been appointed to the civilian advisory committee looking at the possible health effects of the Sanguine transmissions.

This committee was presented with a corpus of data generated by some twenty or so programmes, run or funded by the US Navy, which contained enough data to indicate that there were biological effects which were potentially hazardous to human health. The frequencies were 45Hz and 75Hz and, after considering the evidence, the committee unanimously felt that major segments of the

## NON-IONIZING RADIATION



*The UK: new houses are built under power lines*

American population were "currently at risk" from power-line fields.

Shortly afterwards, a new major power line was to be built through New York State and Becker found that the Navy would not admit to possessing their data or the committee report. He decided that he needed to agree to testify. The power companies, supported by the federal government, had an interest in seeing that the hearings did not take place or, if they did, that the result cleared electromagnetic fields as providing no health hazard. The line was given the go-ahead. To quote Robert Becker subsequently: "Now it's impossible for

me to prove this, but the coincidences in time and place are too evident not to believe that there was a relationship with this public hearing. Prior to my involvement with this public hearing I was supported by several granting agencies to do my research work. I had access to the scientific literature so that my papers could get published in the appropriate journals. Following the opening of the hearings we lost every research grant that we had. In addition we were subject to administrative harassment by the agency for which I was basically working, the United States Veterans Administration. The entire circum-

stances were apparently designed to diminish my enthusiasm for proceeding with these public hearings".

Becker's crime was to establish a clear link between power lines and health hazards. His punishment was scientific exile. Now, at 59, he is enjoying a forced early retirement, despite his world-wide reputation for original research work. (GBI, 1984)

An interesting settlement occurred earlier this year when the widow of a New York Telephone Co. radio technician settled a 1976 suit against the RCA Corporation for \$250 000. Mrs Yannon charged that RCA was responsible for the wrongful death of her husband due to long-term microwave exposure. Yannon died in 1974 at the age of 62; in his final months, he lost almost all his sight, memory, speech and motor coordination. The workers' compensation panel had earlier ruled that "There was a direct causal relationship between (Yannon's) exposure to microwave radiation during his employment and his subsequent disability, all of which ultimately resulted in his death". (Microwave News, May/June 1989)

### CHILDHOOD CANCER IN THE UK

Turning to the CEGB, we get fairly constructive response, at least in terms of hopeful-sounding words. Their short document "UK Electricity Supply Industry Research on Power-frequency Electric and Magnetic fields and possible Health effects", published in September 1989, is most promising.

Its historical record, however, leaves much to be desired. A study called "Overhead Power Lines and Childhood Cancer" done in conjunction with the University of Leeds and Cockridge Hospital, Leeds, was first published at an IEE meeting in December 1985. This is the only study they have published following up the work of Nancy Wertheimer et al., and it has very significant shortcomings.

The work coming from other countries has pointed out possible links between childhood cancers and 50Hz (Sweden, Ref. Tomenius, first announced in 1982) and 60Hz (USA Wertheimer et al., 1976 onwards) fields in the order of 200nT to 300nT. Indeed, the 1987 NYSPLP report points out the possibility that 10 to 15% of all childhood cancer cases in the USA might be attributable to power-frequency magnetic fields of around 250nT and above.

The Wertheimer and Tomenius studies are quoted as the background to the Leeds study and so it would seem sensi-

ble to include some areas where the background 50Hz magnetic fields were likely to exceed 250nT.

So what do we find when we look at the data presented in the report? Firstly that the magnetic fields were only calculated by computer modelling of the overhead power lines, and not actually measured. This was specifically to exclude locally generated fields (see later).

Secondly, that out of the 376 case and 590 control children included in the analysis, 361 cases and 567 controls were below 10nT, a further 9 cases and 15 controls were in the range 10nT to 100nT, and only 6 cases and 8 controls were in calculated fields above 100nT.

If we take the highest figure suggested for childhood cancer as being 15% of all childhood cancer cases due to fields of 200nT or above, and allow that the six cases were indeed in fields over 200nT, and that we had an ideal sample, then the researchers were likely to have included nine-tenths of a case in their survey!

The conclusion that "within the bounds of the present analysis, there is no apparent relationship between overhead power lines and childhood cancer" was therefore to be expected, if not actually planned for in the study methodology.

This is hardly surprising, since the then CEGB Chief Medical Officer, Dr John Bonnell, is on record as saying (1984) "At the present time I do not believe any action is justified. If we accepted the dangers it would mean an enormous turn about for industry and for the country as a whole. There are no contingency plans to cope with such a turn about. If there are any effects at all due to exposure to electric fields then they are slight, and it is certainly extremely difficult to disentangle them from other causes of ill health." (GBI,1984). Dr Bonnell retired at the end of 1986 and was replaced by Dr Robin Cox, who seems to have a more enlightened attitude.

The study is claimed to have been designed to give power lines a clean bill of health. It was based on calculated fields from high-voltage power lines to exclude the effects of street and house wiring. In other words, it was only designed to try and detect a link between childhood cancer and high-voltage power lines, rather than the more relevant 50Hz magnetic fields from high-current domestic wiring.

The study does report on a sample of 44 properties, not otherwise included in the investigation, where the internal

magnetic fields were measured. The highest field of 130nT was reported as being due to a neighbouring overhead local power line and not a high-voltage transmission line. This agrees with my findings. For example, in my own house, which has about an 8m gap from the outside wall to a three-phase pole-mounted 415V street feeder, the magnetic field at times of high demand is around 150nT in the nearest bedrooms. In addition, the house has off-peak storage radiators which produce an additional field of about 300nT at a distance of 1m. (I intend to change my heating system very soon!) Another cause of magnetic fields comes from local bonding of neutral to earth, as in PME systems. This can cause surprisingly high earth currents to flow, as the ground shares the return current with the neutral.

A second study of adult leukaemia and allied diseases covering Yorkshire and part of Lancashire is in progress, with results expected by the end of 1989. However, this suffers from the same basic methodology and only uses magnetic fields calculated as radiating from high-voltage transmission lines.

A good place to run a detailed study would have been the village of Fishpond, Dorset, in which documentary evidence points strongly to adverse health effects of power transmission lines. The CEGB and NRPB have not investigated the evidence at all thoroughly. (See *Electromagnetic Man*, Ch.8 - ref. below)

## SUICIDES

Initially, when Dr Stephen Perry started investigating the possible relationship between power lines and suicides and clinical depression in the West Midlands, the CEGB and local electricity Boards were extremely helpful and provided copies of their maps showing the power lines. When he told them that there were three times as many suicides

**...10 to 15 percent of all childhood cancer cases in the USA might be attributable to power frequency magnetic fields of around 20ont and above**

as there should have been in the urban roads that carried their heavy underground cables, they stopped giving him information. When the study was published, it showed that people living in high magnetic fields next to power lines were 40% more likely to commit suicide. Public money has not been forthcoming to replicate this study. In Britain the electricity industries are accountable on health matters to a watchdog committee, the majority of whose members are from the CEGB. This committee is accountable to the Minister of Energy who, in turn, is accountable to Parliament. This exercise in self policing has so far given UK power lines a clean bill of health.

Despite the growing weight of evidence, the authorities in Britain continue to allow houses to be built near to power lines, even though the authorities in a number of other countries have taken action to restrict this. It should be noted that it is usually the governments, state authorities or councils who define and enforce Right of Way (ROW) distances, and not the power utilities.

## TESTED IN COURT

A good example of the US controversy is the case of the Klein Independent School, Houston, Texas. The problem had begun in 1981 when the Houston Lighting and Power Company had instituted condemnation proceedings over about eight acres of the school land for the ROW of a new 345kV transmission line. It then built the line which ran within 90m of a primary school, 40m from an intermediate school and 75m from a secondary school. After a long and bitterly fought court case, the jury awarded \$104 275 actual damages for use of the land and \$25 000 000 punitive damages "as an example that the utility's conduct will not be tolerated". The jury went on to find that the reasonable cost to the school district of replacing or restoring its property and facilities to their original condition would be \$42 113 120.

Since then, there have been numerous appeals and the line has been shut down for extended periods. In November 1987 the Appeals Court reversed the \$25M punitive damages on the grounds that the utility had been in technical compliance with the Texas Property Code. At the same time, however, they did agree that the jury had been correct in finding "clear and convincing evidence" of potential health hazards caused by electromagnetic fields, and that the utility had abused its powers by siting a 345kV line on school

property. Meanwhile the Houston Lighting & Power Co. had removed the power line and re-routed it at a cost of more than \$M8.5. Since then, more private litigations have followed.

There is no comparable concern in this country. The proudly announced £500 000 for research into these areas pales rather when one realises that the CEGB (et al.) are reported to have recently spent £400 000 on changing all their letterheads and stationery in readiness for privatization. There is also a purported £100 000 000 allocated for advertising and promotional purposes when the sale is launched.

Privatization also raises some interesting questions as regards liability if and when health effects are proven in court. National Grid will only be responsible for the 400kV and 275kV transmission lines (hence the survey methodology?) and the 12 Area Boards will be responsible for the distribution from 132kV through to the 240V domestic supplies. If the local distribution wiring is responsible for the main magnetic fields, who will pay the bill for the major re-wiring job that is likely to be necessary? It makes the Area Boards look like a very dubious investment at present.

In 'Electromagnetic Man', Dr Cyril Smith, one of the leading UK researchers in this field, states that if he had young children, he would only buy a house if there were no environmental sources of coherent electromagnetic fields causing more than 15nT magnetic flux density within the house. This statement is based on his interpretation of the data available at the start of 1989. If this became a generally accepted requirement, it would have a dramatic effect on the UK housing market. His work also seems to show that one person in a thousand is appreciably allergically affected by EM fields - amounting in Britain to approximately 55 000 people functioning substantially below par.

### MORE RESEARCH NEEDED

Roger Coghill's work points an accusing finger at the effects of low levels of 50Hz fields, especially when present in our sleeping areas, affecting all of our immune systems and bodily repair systems. He postulates that this will give rise to larger outbreaks of such diseases as salmonella and listeria and is likely to play a significant role in ME and AIDS susceptibility. Coghill's requests for funding to do a medium-scale epidemiological survey of cot death (SIDS) sites, to follow up his earlier self-funded small survey, have been



**John Wakeham, secretary of state for energy:**

*"After privatisation, the part of the CEGB responsible for a transmission system will form the National Grid Company and will continue the work already started to investigate the possible effects to human health of electro-magnetic fields emanating from power cables. In addition, independent research on the subject is also undertaken at a number of universities and hospitals and government is kept informed of these developments via officials in the Departments of Energy and Health, the Health and Safety Executive, and the National Radiological Protection Board."*

turned down. SIDS accounts for some 10 000 infant deaths per year in the USA and for between 2000 and 3000 in the UK.

I suggest that independent university-monitored research into the non-thermal effects of alternating electric and magnetic fields on peoples' health is carried out as a matter of extreme urgency. This work should be funded without bias by the Government. It should include power line fields, ELF pulsed-RF fields, and electric and magnetic fields generated by computers, VDUs, and other common pieces of electronic equipment that we live with.

Until the results of this research become available, a moratorium should be placed on all new building or routing of power lines which causes 50Hz fields in houses to exceed very cautiously set limits. I would suggest somewhere in the order of 100nT and 1kV/m at the house wall might be appropriate.

The link between smoking and

lung cancer was obvious to most people for many years before it was officially admitted. At least individuals could choose whether or not to smoke. It is not so easy to avoid power line fields or the fields from computers and VDUs. The effects of EMF exposure and smoking are directly comparable; long-term exposure to either doesn't necessarily produce a malignancy. However, pathological effects can be noted in most cases.

Final food for thought. The report of the 1977 Working Group on Inequalities in Health placed electrical engineers highest (19.4 men per 1000 aged 15-64) and university lecturers lowest (2.87 per 1000) in the male death league.

### SUGGESTED READING

There are vast quantities of reports and many books on the subject. I have selected a few that are relatively easy to obtain and provide an up-to-date point from which to start.

Electromagnetic Man, Health & Hazard in the Electrical Environment, by Cyril Smith and Simon Best, pub. 1989, Dent, 17.95.

Currents of Death: Power Lines, Computer Terminals and the Attempt to Cover Up their Threat to Your Health. Paul Brodeur, pub. 1989, Simon & Schuster, USA.

Electromagnetic News, P.O.Box 25, Liphook, Hants, GU30 7SE. 6 issues per year. 3 per issue or 15 per year.

Microwave News, P.O.Box 1799, Grand Central Station, New York, NY 10163. A mine of information! Bimonthly. 3 issues \$150 (outside USA.)

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*Alasdair Philips is the national contact for Electronics and Computing for Peace, a national network of electronics and computing professionals who are concerned about the implications of their profession.*

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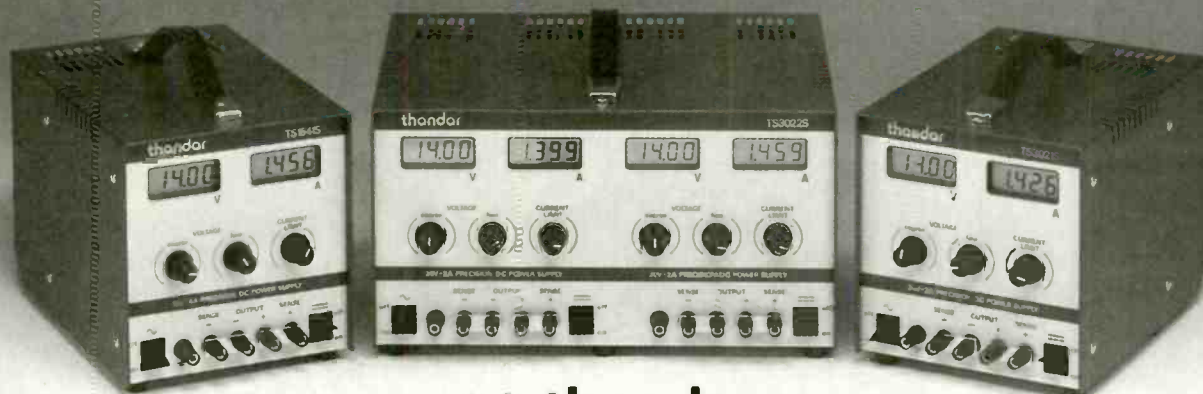
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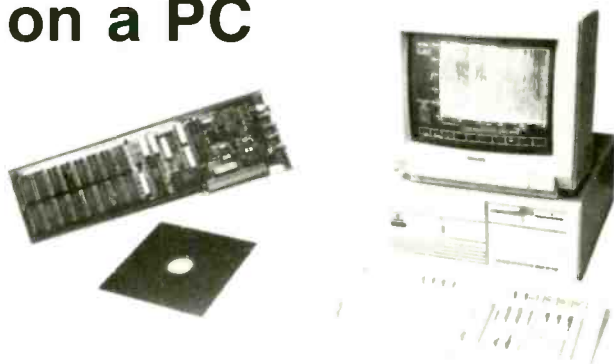
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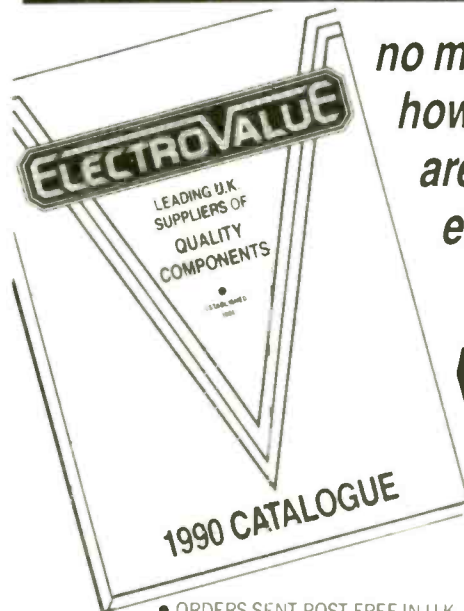
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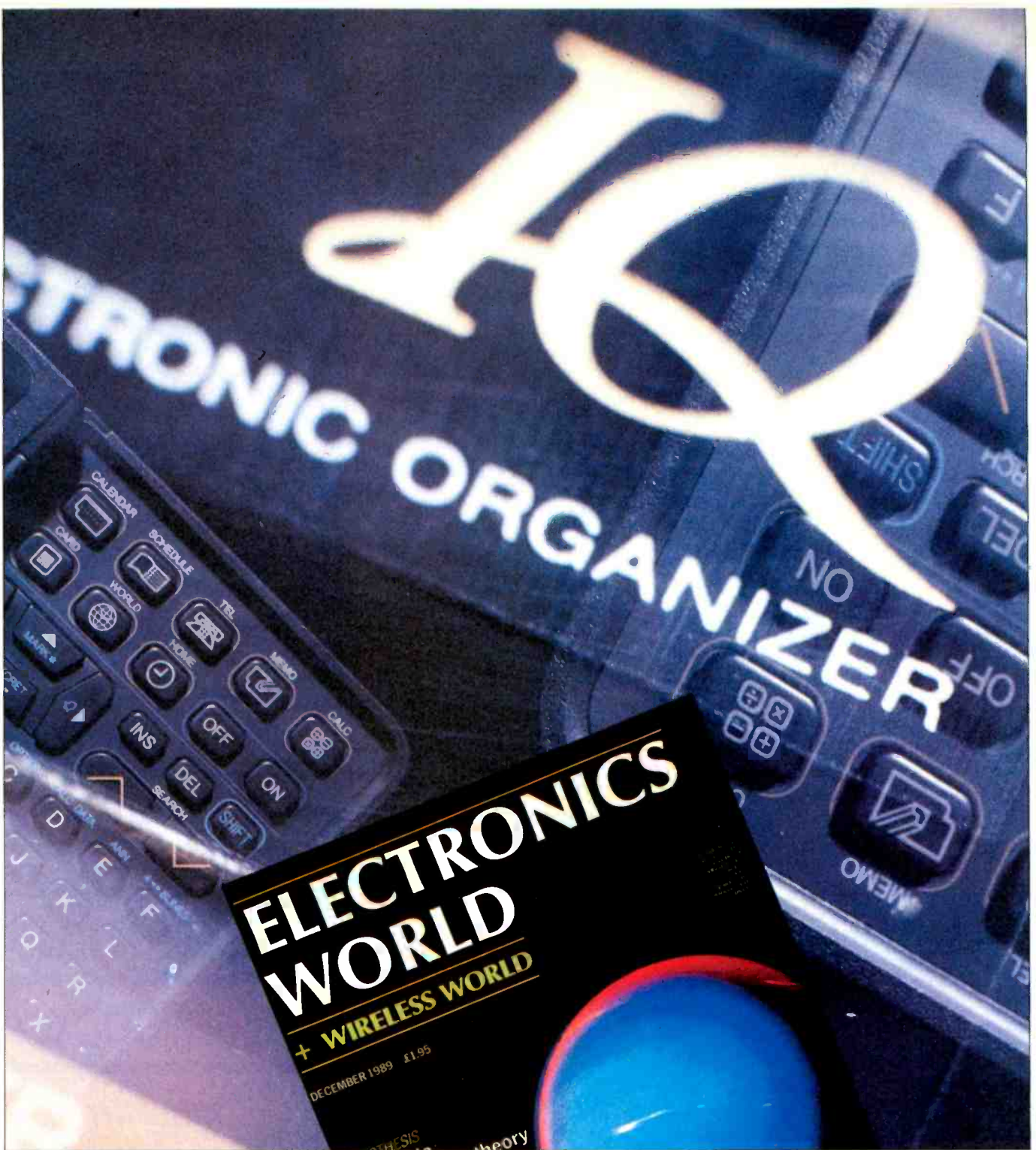
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# Designers' guide to switched mode ICs

**W**E make no pretence that the following guide is comprehensive or that it represents the last word in switched-mode technology. However, it does enable useful comparisons between readily obtainable parts from a spread of manufacturers to be made.

Most of the devices listed here incorporate on-chip switching elements which will happily operate to the maximum quoted switching frequency with stability and minimal losses in low-current applications. Nearly all the devices may be used to switch external transistors provided that suitable allowance is made for the extra switching time involved.

## Current mode control

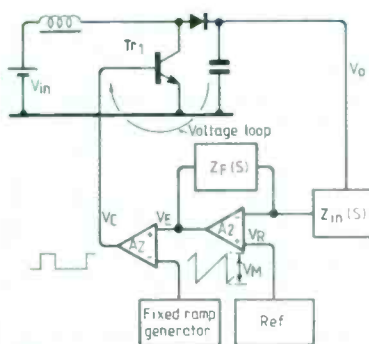
Double control loops are now making an appearance in switched-mode power supply design. The so called current mode PWM controllers offer some advantage in obtaining precise control at high switching frequencies.

In essence, a second comparator system monitors current in the switching element, enabling direct control of the switching period on a cycle-by-cycle basis. This feeds an error signal forward to the switch and means that the circuit doesn't have to wait for major perturbations of the main voltage control loop - the one that is common to all SMPS regulators - in responding to shifts in the regulator input voltage.

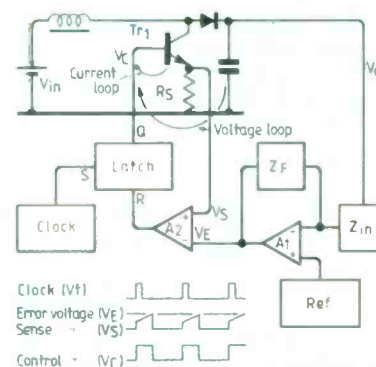
Changes in input voltage directly affect the current flowing in the switch inductor. These are sensed by monitoring the current flowing in the switching transistor during its on time. The sense circuit extends or curtails the existing duty cycle to prevent inductor core saturation.

The current loop can only counteract input voltage variations. Changes in load current (output voltage) are handled by the voltage control loop common to all SMPS regulators.

It has never been easier to design switched mode power supplies. The increasing sophistication of control and switching ICs makes them easier to use. Watt for watt, switching chips often have a similar component count to their linear counterparts.

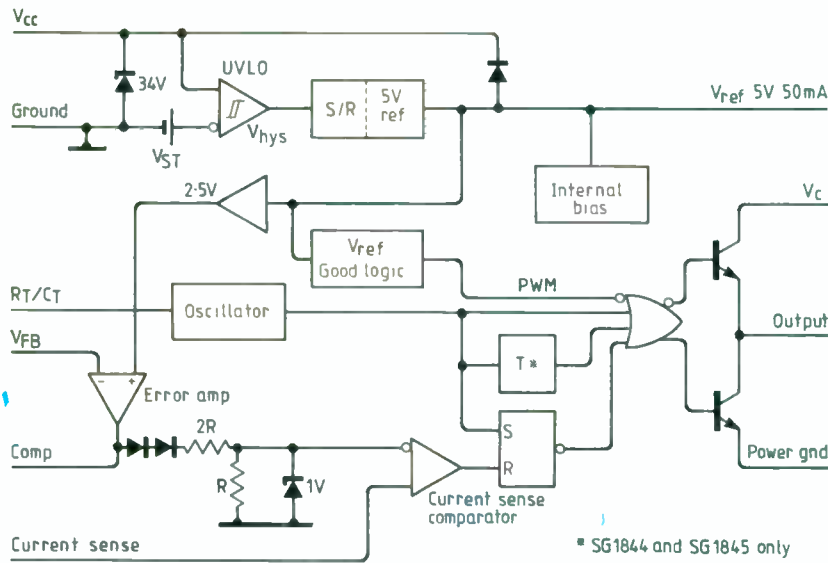


**Voltage mode. SMPS with a single voltage loop relies solely on reference comparison with the convertor output voltage for pulse width control. This can lead to inductor saturation with load transients.**



**Current and voltage mode. Monitoring the switch current can terminate the conduction cycle before inductor saturation occurs. Splitting the control loop also offers tighter control with less overshoot.**

# DESIGN



**UC3842 block diagram. Typical current mode controller chip with single totem-pole output.**

HS7107

**NATIONAL SEMICONDUCTOR**  
Hybrid 7A multimode high efficiency switching regulator.  
Mode: Voltage  
Output type: uncommitted transistor (1)  
Max output current 8000mA  
Max output voltage 100V  
Max operating frequency 300kHz  
Input voltage limits 100, 10V  
Undervoltage lockout: no  
Soft start facility: no

The device is housed in a T03 package which allows 25W maximum power dissipation. The HS7067 is similar except for a supply voltage range of 10 to 60V.

SG3530

**SILICON GENERAL**  
High speed current mode PWM controller.  
Mode: Current  
Output type: totem pole (1)  
Max output current 2000mA  
Max output voltage 17V  
Max operating frequency 2000kHz  
Input voltage limits 17, 13V  
Undervoltage lockout: yes  
Soft start facility: yes

This device is similar to the SG3528 except that the duty cycle is variable from 0 to 100%.

SG3528

**SILICON GENERAL**  
High speed current mode PWM controller.  
Mode: Current  
Output type: totem pole (1)  
Max output current 2000mA  
Max output voltage 17V  
Max operating frequency 2000kHz  
Input voltage limits 17, 13V  
Undervoltage lockout: yes  
Soft start facility: yes

This device allows a maximum duty cycle of 50%. Many protection features are built in allowing use as a versatile control chip.

MAX641/2/3

**MAXIM**  
These devices are fixed-output 5V 10W step-up switching regulators  
Mode: Voltage  
Output type: open drain (1)  
Max output current 2000mA  
Max output voltage 0V  
Max operating frequency 45kHz  
Input voltage limits 17, 2V  
Undervoltage lockout: no  
Soft start facility: no

Low battery comparator is provided on chip. Output voltage may be varied using a voltage divider. The power switch is provided on chip.

μA78S40

**FAIRCHILD**  
Universal switching regulator subsystem.  
Mode: Voltage  
Output type: totem pole (1)  
Max output current 1500mA  
Max output voltage 40V  
Max operating frequency 0kHz  
Input voltage limits 40, 3V  
Undervoltage lockout: no  
Soft start facility: no

A freewheel diode is provided on-chip. The device is capable of switching 1.5A of output current.

L4970

**SGS THOMSON**  
10A switching regulator.  
Mode: Voltage  
Output type: mosfet (1)  
Max output current 10 000mA

Max output voltage 50V  
Max operating frequency 500kHz  
Input voltage limits 50, 7V  
Undervoltage lockout: yes  
Soft start facility: yes

The output is configured for buck (step-down) operation. It incorporates a built-in current sense resistor for over-current protection. L4972 is a 2A version in a 20-pin DIL package. L4974 is a 3.5A version in a 20-pin DIL package.

LM3578

**NATIONAL SEMICONDUCTOR**  
8-pin switching regulator with duty cycle variable up to 90%.  
Mode: Voltage  
Output type: uncommitted transistor (1)  
Max output current 750mA  
Max output voltage 34V  
Max operating frequency 100kHz  
Input voltage limits 40, 2V  
Undervoltage lockout: no  
Soft start facility: no

MAX638

**MAXIM**  
Fixed 5V step-down switching regulator.  
Mode: Voltage  
Output type: open drain (1)  
Max output current 525mA  
Max operating frequency 65kHz  
Input voltage limits 17, 2V  
Undervoltage lockout: no  
Soft start facility: no

This device includes the switching power-transistor on chip. The output voltage may be varied from 5V with only an additional voltage divider.

MAX635/6/7

**MAXIM**  
Fixed output-voltage inverting switching regulator.  
Mode: Voltage  
Output type: open drain (1)  
Max output current 525mA  
Max operating frequency 70kHz  
Input voltage limits 17, 2V  
Undervoltage lockout: no  
Soft start facility: no

This device is designed for low power battery operation. A low battery comparator is provided on chip. It is possible to vary the output voltage by using an external voltage divider. The power switch is provided on chip.

MAX634

**MAXIM**  
Micropower switching regulator.  
Mode: Voltage  
Output type: open drain (1)  
Max output current 525mA  
Max output voltage -20V  
Max operating frequency 75kHz  
Input voltage limits 17, 2V  
Undervoltage lockout: no  
Soft start facility: no

Inverting regulator for operation from a battery supply. It includes a low battery indicator circuit. The power switch is on-chip.

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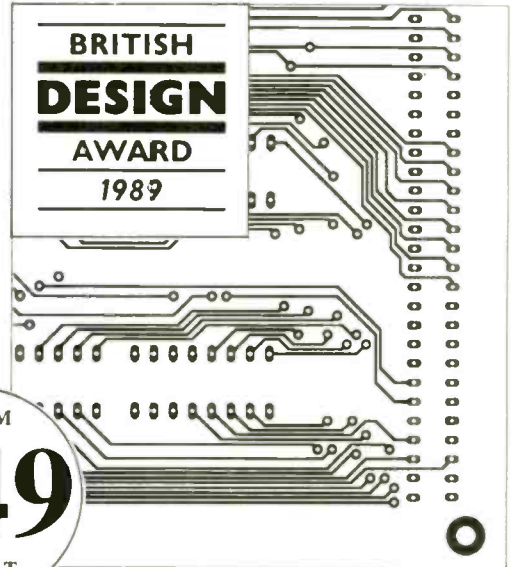
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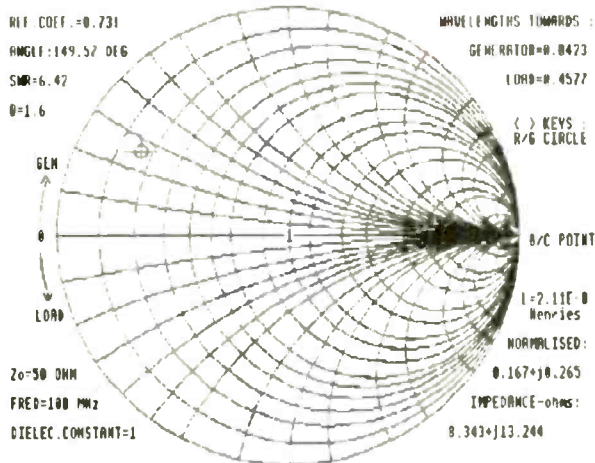
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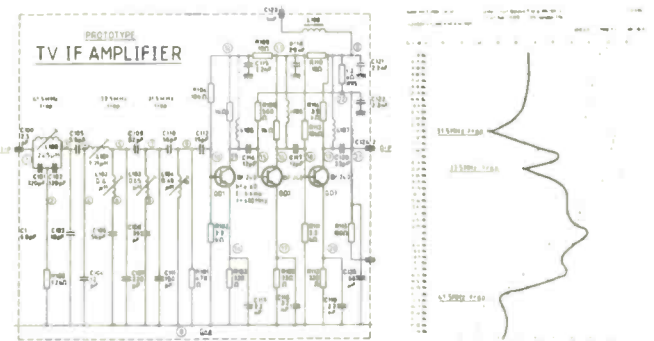
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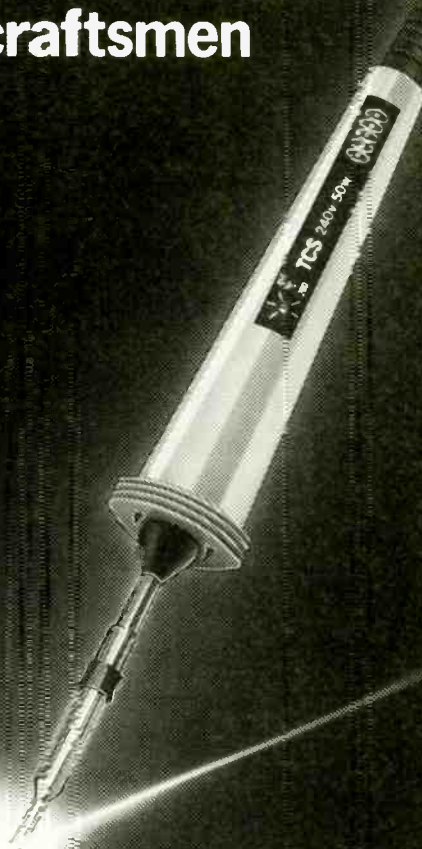
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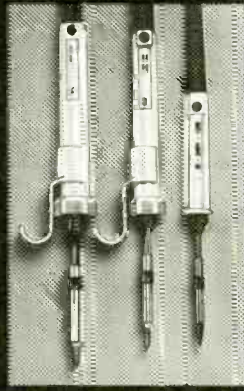
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CIRCLE NO. 119 ON REPLY CARD

**UC3823**

**UNITRODE**  
 High frequency PWM controller.  
 Mode: Voltage/current  
 Output type: totem pole (1)  
 Max output current 500mA  
 Max output voltage 30V  
 Max operating frequency 1kHz  
 Input voltage limits 30, 9V  
 Undervoltage lockout: yes  
 Soft start facility: yes

This is a widely used, versatile device which may be operated in either voltage or current mode.

**UC3841**

**UNITRODE**  
 Programmable off-line PWM controller.  
 Mode: Voltage  
 Output type: open collector (1)  
 Max output current 400mA  
 Max output voltage 40V  
 Max operating frequency 500kHz  
 Input voltage limits 32, 8V  
 Undervoltage lockout: yes  
 Soft start facility: yes

Similar to UC3840 but includes a number of refinements. Very flexible device with protection and monitoring circuitry for most applications.

**UC3840**

**UNITRODE**  
 Programmable off-line PWM controller.  
 Mode: Voltage  
 Output type: uncommitted transistor (1)  
 Max output current 400mA  
 Max output voltage 40V  
 Max operating frequency 500kHz  
 Input voltage limits 32, 8V  
 Undervoltage lockout: yes  
 Soft start facility: yes

All control functions, monitoring and protection functions that are usually required in a power supply are included. The UC3841 supersedes this device for new designs.

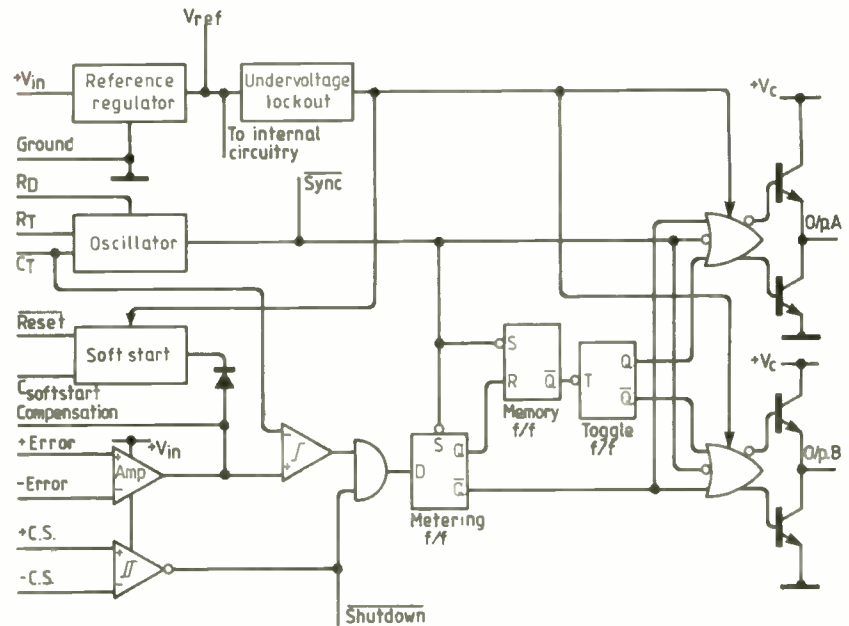
**TL594**

**TEXAS INSTRUMENTS**  
 PWM control circuit.  
 Mode: Voltage  
 Output type: uncommitted transistor (2)  
 Max output current 250mA  
 Max output voltage 41V  
 Max operating frequency 100kHz  
 Input voltage limits 41, 7V  
 Undervoltage lockout: yes  
 Soft start facility: yes

This device contains two op-amps with their outputs or-ed so that the one with the greatest output voltage controls the output pulse-width. This is a relatively simple but useful device.

**TL495**

**TEXAS INSTRUMENTS**  
 PWM control circuit.  
 Mode: Voltage



**SG3526B block diagram. Voltage mode control with double totem-pole output.**

Output type: uncommitted transistor (2)  
 Max output current 250mA  
 Max output voltage 41V  
 Max operating frequency 100kHz  
 Input voltage limits 41, 7V  
 Undervoltage lockout: no  
 Soft start facility: no

Predecessor to the TL595. This device does not feature an undervoltage lockout but in other ways is very similar.

**TL494**

**TEXAS INSTRUMENTS**  
 PWM control circuit.  
 Mode: Voltage  
 Output type: uncommitted transistor (1)  
 Max output current 250mA  
 Max output voltage 41V  
 Max operating frequency 100kHz  
 Input voltage limits 41, 7V  
 Undervoltage lockout: no  
 Soft start facility: no

Predecessor to TL594. This device does not feature an undervoltage lockout but in other ways is very similar.

**TL493**

**TEXAS INSTRUMENTS**  
 PWM control circuit.  
 Mode: Voltage  
 Output type: uncommitted transistor (2)  
 Max output current 250mA  
 Max output voltage 41V  
 Max operating frequency 100kHz  
 Input voltage limits 41, 7V  
 Undervoltage lockout: no  
 Soft start facility: no

This device is similar to TL494 except that one error amplifier has a 0.08V offset for use in current limit sensing.

**MC34060**

**MOTOROLA**  
 PWM control circuit.  
 Mode: Voltage  
 Output type: uncommitted transistor (1)  
 Max output current 250mA  
 Max output voltage 42V  
 Max operating frequency 200kHz  
 Input voltage limits 42, 0V  
 Undervoltage lockout: no  
 Soft start facility: no

Two error amplifiers are provided along with a minimum dead time control input.

**CS593**

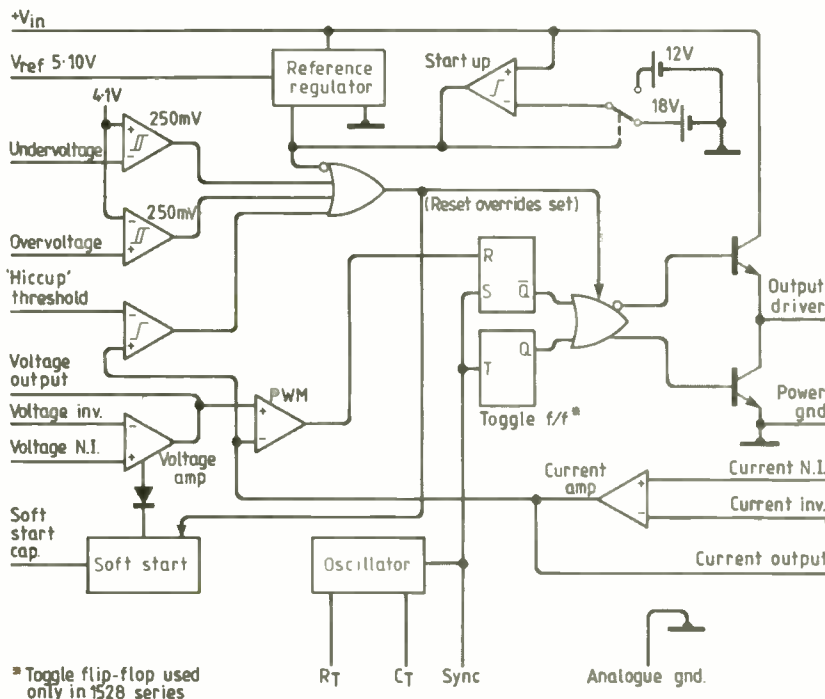
**CHERRY SEMICONDUCTOR**  
 PWM control circuit.  
 Mode: Voltage  
 Output type: uncommitted transistor (2)  
 Max output current 250mA  
 Max output voltage 41V  
 Max operating frequency 300kHz  
 Input voltage limits 41, 7V  
 Undervoltage lockout: yes  
 Soft start facility: no

Similar to TL494/CS494 except that current limit comparator with 80 mV offset is included instead of a standard op-amp. This device is a relatively simple general purpose controller.

**UNITRODE**

Current mode PWM controller.  
 Mode: Current  
 Output type: totem pole (2)  
 Max output current 200mA  
 Max output voltage 40V  
 Max operating frequency 500kHz  
 Input voltage limits 40, 8V  
 Undervoltage lockout: Yes  
 Soft start facility: no

This device is similar to the UC3846 but offers complementary outputs.



**SG3528 block diagram. This current mode controller chip will operate at a maximum switching frequency of 2MHz.**

## UC3846

**UNITRODE**  
Current mode PWM controller.  
Mode: Current  
Output type: totem pole (2)  
Max output current 200mA  
Max output voltage 40V  
Max operating frequency 500kHz  
Input voltage limits 40, 8V  
Undervoltage lockout: yes  
Soft start facility: no

This device includes a shutdown pin and most of the circuitry required to control a power-supply using a half or full bridge configuration.

## TL595

**TEXAS INSTRUMENTS**  
PWM control circuit.  
Mode: Voltage  
Output type: uncommitted transistor (2)  
Max output current 200mA  
Max output voltage 40V  
Max operating frequency 100kHz  
Input voltage limits 41, 7V  
Undervoltage lockout: yes  
Soft start facility: no

This device contains a 39V zener diode so that the device can provide a housekeeping supply by using the diode as a shunt regulator. A pulse steering input which can be used to inhibit operation is provided.

## SG3527A

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage

Output type: totem pole (2)  
Max output current 200mA  
Max operating frequency 500kHz  
Input voltage limits 35, 8V  
Undervoltage lockout: yes  
Soft start facility: yes  
This device is similar to the SG3525A except that the outputs are complementary.

## SG3525A

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage  
Output type: totem pole (2)  
Max output current 200mA  
Max operating frequency 500kHz  
Input voltage limits 35, 8V  
Undervoltage lockout: yes  
Soft start facility: yes

This device is a widely used control chip. Note the transconductance-type error amplifier which has an output impedance of approximately 4MΩ.

## RC4191

**RAYTHEON**  
Micro-power switching regulator.  
Mode: Voltage  
Output type: open collector (1)  
Max output current 150mA  
Max output voltage 30V  
Max operating frequency 75kHz  
Input voltage limits 30, 4V  
Undervoltage lockout: no  
Soft start facility: no

This device is designed for battery operation. A low battery comparator and output are provided.

## UC3850

**UNITRODE**  
Switching power supply control system  
Mode: Voltage/current  
Output type: uncommitted transistor (2)  
Max output current 100mA  
Max output voltage 40V  
Max operating frequency 200kHz  
Input voltage limits 40, 5V  
Undervoltage lockout: yes  
Soft start facility: yes

This device is a high functionality controller that may also be used in current-mode control systems. All the usual protection circuitry is included.

## SG3529

**SILICON GENERAL**  
Regulating PWM controller.  
Mode: Voltage  
Output type: uncommitted transistor (2)  
Max output current 100mA  
Max output voltage 60V  
Max operating frequency 400kHz  
Input voltage limits 40, 7V  
Undervoltage lockout: yes  
Soft start facility: no

This is a modified SG3524B with uncommitted input to the PWM comparator to simplify feed-forward operation. Note the transconductance-type error amplifier which has an output impedance of approximately 4MΩ.

## SG3526B

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage  
Output type: totem pole (2)  
Max output current 100mA  
Max operating frequency 500kHz  
Input voltage limits 35, 8V  
Undervoltage lockout: yes  
Soft start facility: yes

This device is an improved version of SG3526 featuring much faster shutdown and a more accurate voltage reference along with other enhancements.

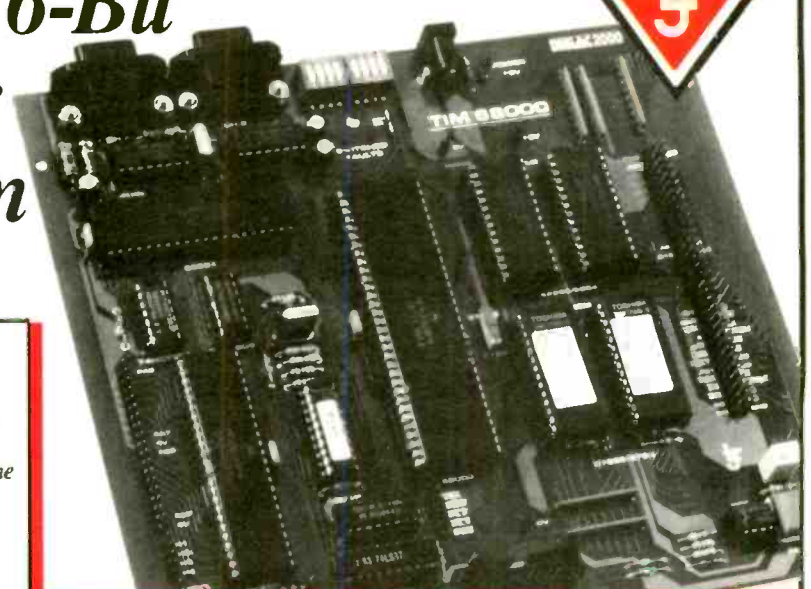
## SG3526

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage  
Output type: uncommitted transistor (1)  
Max output current 100mA  
Max operating frequency 350kHz  
Input voltage limits 35, 8V  
Undervoltage lockout: yes  
Soft start facility: yes

This device contains all the control and protection circuitry required for most power-supply designs. Note the transconductance-type error amplifier which has an output impedance of approximately 4MΩ.

continued over page

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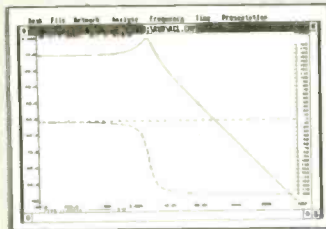
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Frequency response of a low pass filter circuit

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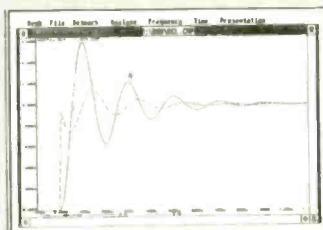
### 2 DC Quiescent analysis

SPICE•AGE analyses DC voltages in any network and is useful, for example, for setting transistor bias. Non-linear components such as transistors and diodes are catered for. (The disk library of network models contains many commonly-used components - see below). This type of analysis is ideal for confirming bias conditions and establishing clipping margin prior to performing a transient analysis. Tabular results are given for each node: the reference node is user-selectable.

Node	Volt	Current	Power	Phase
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
3	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
4	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
5	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
6	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
7	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
8	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
9	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
10	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
11	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
12	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
13	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
14	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
15	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
16	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
17	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
18	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
19	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
20	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
21	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00
22	1.5419E-01	1.5419E-01	2.3768E-02	0.0000E+00

DC conditions within model of 741 circuit

## NEW: HANNING WINDOW: RESULTS LOGFILES



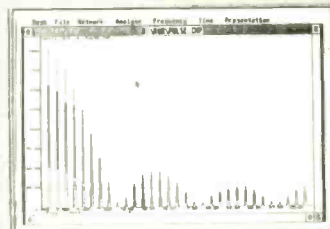
Impulse response of low pass filter (transient analysis)

### 3 Transient analysis

The transient response arising from a wide range of inputs can be examined. 7 types of excitation are offered (impulse, sine wave, step, triangle, ramp, square, and pulse train); the parameters of each are user-definable. Reactive components may be pre-charged to steady-state condition. Up to 13 voltage generators and current generators may be connected. Sweep time is adjustable. Up to 4 probe nodes are allowed, and simultaneous plots permit easy comparison of results.

### 4 Fourier analyses

SPICE•AGE performs Fourier transforms on transient analysis data. This allows users to examine transient analysis waveforms for the most prevalent frequency components (amplitude is plotted against frequency). Functions as a simple spectrum analyser for snapshot of transients. Automatically interpolates from transient analysis data and handles up to 512 data values. Allows examination of waveform through different windows. Powerful analytical function is extremely easy to use.



Spectrum of rectangular pulse train (Fourier analysis)

If your work involves designing, developing or verifying analogue or digital circuits, you will wonder how you ever managed without *Those Engineers* circuit Simulation Software.

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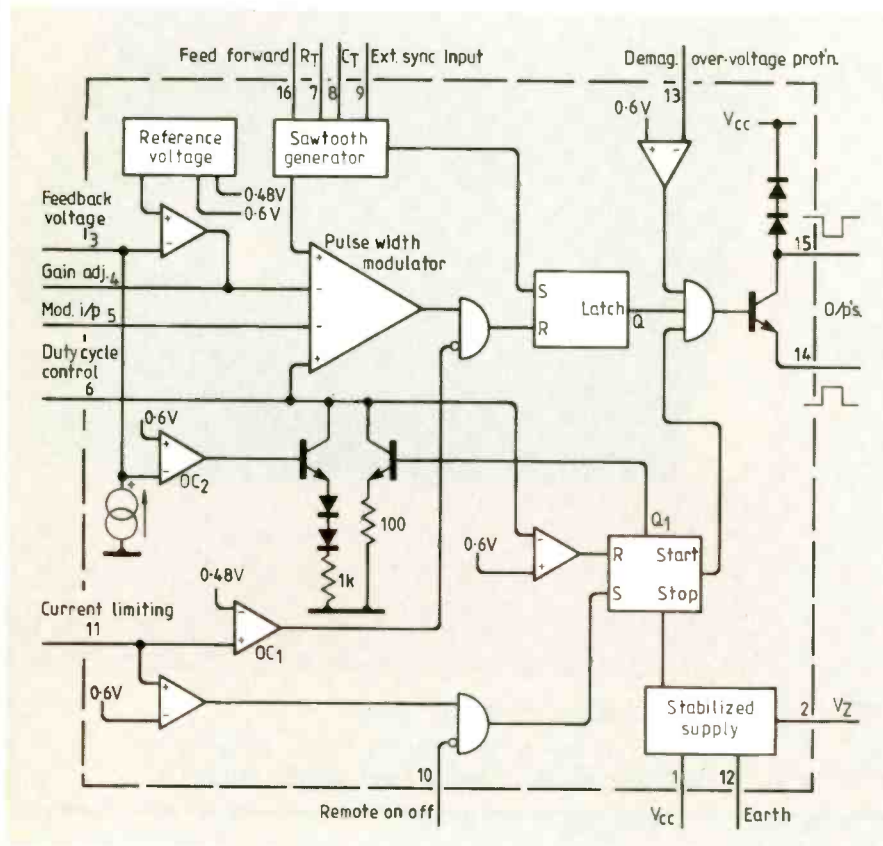
Telephone: Charles Clarke on 01-435 2771 for a demonstration disk.

# Those Engineers LTD

106a Fortune Green Road · West Hampstead  
London NW6 1DS  
Tel: 01-435 2771 · Fax: 01-435 3757

CIRCLE NO. 117 ON REPLY CARD

# DESIGN



**NE5560 block diagram. Voltage mode device with minimum deadtime control.**

## SG3524B

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage  
Output type: uncommitted transistor (2)  
Max output current 100mA  
Max output voltage 60V  
Max operating frequency 400kHz  
Input voltage limits 40, 7V  
Undervoltage lockout: yes  
Soft start facility: no

This is an improved version of SG3524 with greater drive capability and an undervoltage lockout circuit. This device is very widely used. Note the transconductance-type error amplifier which has an output impedance of approximately 4M $\Omega$ .

## NE5562

**PHILIPS**  
PWM control circuit.  
Mode: Voltage  
Output type: totem pole (1)  
Max output current 100mA  
Max output voltage 0V  
Max operating frequency 600kHz  
Input voltage limits 16, 9V  
Undervoltage lockout: yes  
Soft start facility: yes

Device contains over-voltage protection, two current limiters, feed-forward control, demagnetization sense input, loop fault protection and other features.

## SG3524

**SILICON GENERAL**  
Regulating PWM circuit.  
Mode: Voltage  
Output type: uncommitted transistor (1)  
Max output current 50mA  
Max output voltage 40V  
Max operating frequency 300kHz  
Input voltage limits 40, 8V  
Undervoltage lockout: no  
Soft start facility: no

This device is a basic control chip. The transconductance-type error amplifiers have a 4M $\Omega$  output impedance.

## NE5560

**PHILIPS**  
PWM control circuit.  
Mode: Voltage  
Output type: uncommitted transistor (1)  
Max output current 40mA  
Max operating frequency 100kHz  
Input voltage limits 18, 9V  
Undervoltage lockout: yes  
Soft start facility: yes

Clamped to the supply voltage through two diode drops (1.4V). This device includes a minimum dead time control, a current limit circuit and remote on/off along with an over-voltage protection or demagnetization input (to prevent core-walking).

## NE5561

**PHILIPS**  
PWM control circuit.  
Mode: Voltage  
Output type: open collector (1)  
Max output current 20mA  
Max operating frequency 100kHz  
Input voltage limits 18, 9V  
Undervoltage lockout: yes  
Soft start facility: no

Limited to the positive supply voltage plus two diode drops (1.4V). Soft start may be implemented with a few external components. A current sense comparator is provided for cycle by cycle current limiting.

## UC3842/3/4/5

**UNITRODE**  
Current-mode PWM controller.  
Mode: current  
Output type: totem pole (1)  
Max output current 1mA  
Max output voltage 30V  
Max operating frequency 500kHz  
Input voltage limits 30, 16V  
Undervoltage lockout: yes  
Soft start facility: no

This device along with UC3844 and UC3845 are simple, easy to use controllers. UC3844 and UC3845 are limited to a maximum duty cycle of 50% whereas the UC3842 and UC3843 go up to 100%. The undervoltage lockout thresholds are 16V (on) and 10V (off) for the UC3842 and 3844, 8.5V (on), 7.9V (off) for the UC1843 and UC1845.

## TDA4601

**SIEMENS**  
Control IC for switched-mode supplies.  
Mode: Voltage  
Output type: emitter follower (1)  
Max operating frequency 75kHz  
Input voltage limits 18, 8V  
Undervoltage lockout: yes  
Soft start facility: yes

This device is housed in a 9-pin single-in-line package. This device is designed for use in self-oscillating flyback converters.



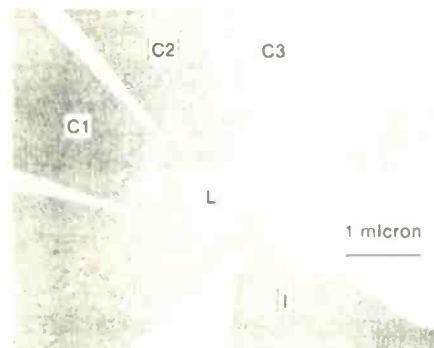
## Keeping control of cool beams

Imagine being able to apply Snell's Law of refraction to a beam of electrons travelling through solid gallium arsenide. Imagine being able to move the beam left or right, to send it through prisms and gratings. Imagine being able to have such a beam in the first place without it scattering as the electrons collide with atoms and other electrons.

Researchers at IBM's Thomas Watson centre in New York have managed all this in a new field of research called ballistic electronics. The work has the potential to drastically reduce the number and size of devices in future computers.

The snag is the temperature. The GaAs has to be cooled down to 5.4K to reduce the motion of atoms inside the material so lessening the chance of collision with the electrons. This can increase the mean free path of the electrons to  $1\mu\text{m}$ . Using particularly pure GaAs much longer distances have been achieved.

The next step is to place a small lens shaped piece of metal above the GaAs and apply a voltage to it. This creates a lens shaped potential barrier in the GaAs which the electrons have to pass through. The lens slows down and



**Ballistic electrons go through injector I and are focussed by the lens L into one of three collection areas C1, C2 and C3**

focusses the electrons in a similar way to how a glass lens focusses light.

The behaviour of the electrons at a barrier between high and low voltages is also very similar to the way light behaves at say a glass/water barrier. If the electrons hit the barrier at an angle they will leave the barrier at a different angle. Change the voltage and the angle is changed.

Dr Mordehai Heiblum, who is leading the research, said: "It is very similar to Snell's Law. The potential is analogous to the refractive index."

This means the electrons can be

steered as they travel through a device. So, whereas a normal semiconductor device can have only two states of on or off, a ballistic device could have many states depending on the angle through which the beam is deflected.

Heiblum said: "You can have a variable number of states. A multistate device will mean structures with less devices."

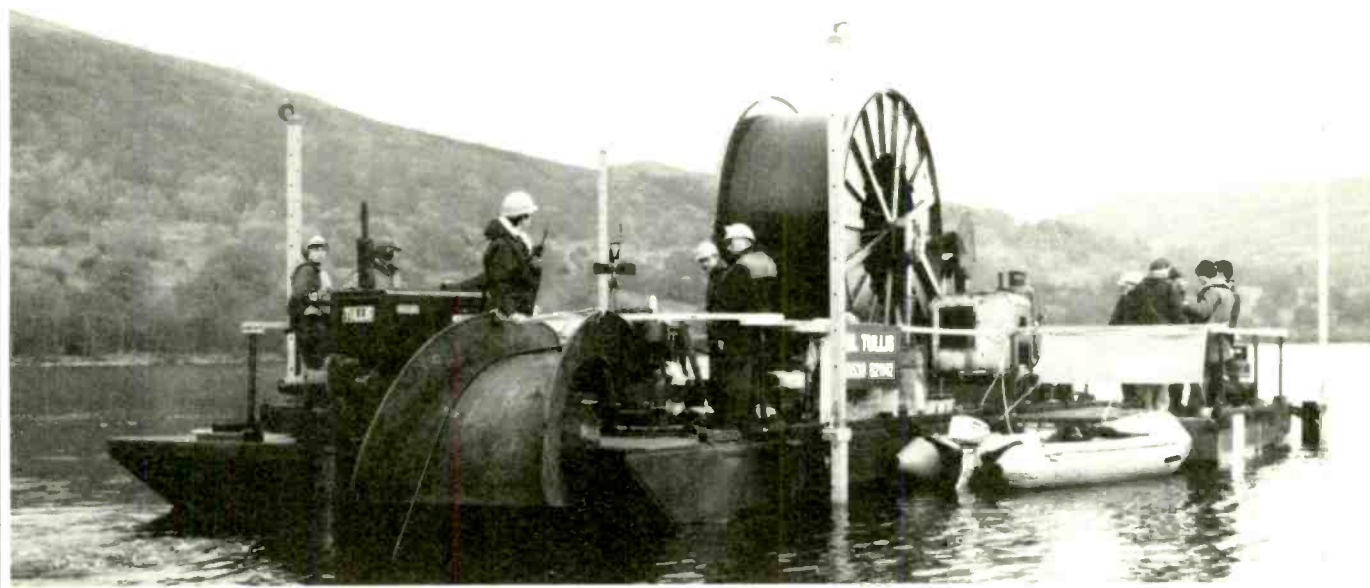
He added: "The mean free path is only long for low temperatures. But if it is found that this technology gives a tremendous advantage then in the future they will find ways to get round it."

"You can carry the field of optics over to the field of ballistic electronics. I am convinced now that there will be a tremendous amount of work into ballistic electronics. We can already do prisms, gratings and so on."

Heiblum managed a form of ballistic electron transport back in 1985 at temperatures as high as 77K but with GaAs only  $0.05\mu$  thick. Last year the researchers managed to achieve ballistic travel with positive 'holes'.

Early this year they managed the relatively long lengths that led to the development of the lens.

*Tourists enjoying the Lake District beauty of Ullswater recently had their holiday spell broken as this strange looking craft trundled its way across the previously calm surface. But the specially made mobile pontoon was there to protect the environment. The problem started when British Telecom realised that, to switch its 350 customers in Glenridding at the south of the lake to System X, it would have to lay a new fibre optic cable. Rather than digging up the wonderful countryside it decided to lay the 15km 27ton one inch diameter cable under the water from Glenridding to Pooley Bridge. It was not practical to bring one of its existing cable laying craft over land to the lake so it made this monstrosity. Thankfully the view was only spoiled for a day and Glenridding customers can use System X while watching the deer prancing along the banks of a once again still Ullswater.*



## TI patent bonanza

More than 30 years after its invention, the integrated circuit has been patented in Japan. The patent has been awarded to Texas Instruments because a former employee of the firm, Jack Kilby, invented the technology in 1958.

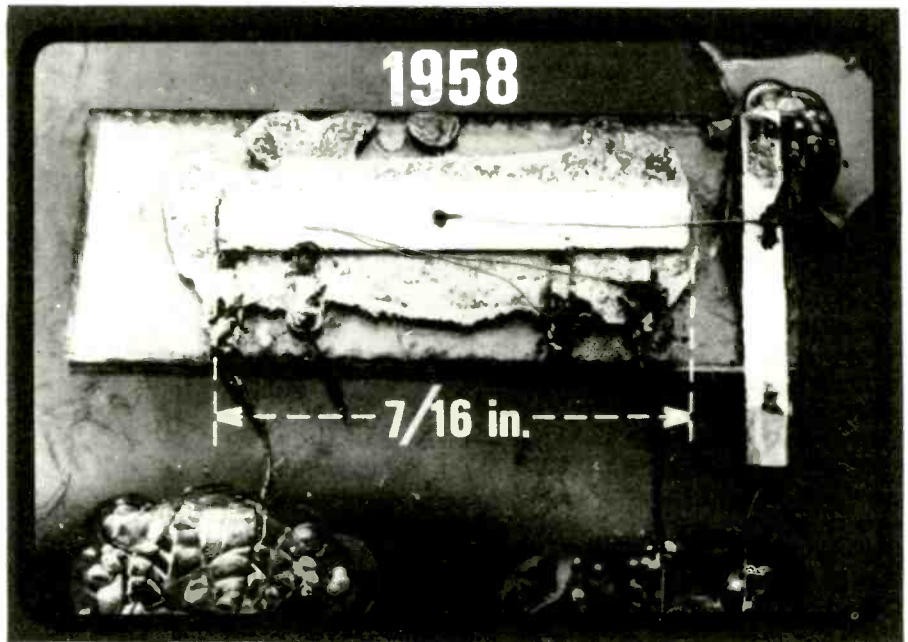
Texas has had patents on ICs in many other countries most of which have expired. In the UK, for example, the patent was granted in 1964 and ran out in 1976. The Japanese patent is due to run out in 2001.

The main difference between this patent and others is the way Texas intends to pursue it. In the past patents have been used as trading agreements rather than sources of revenue. In Japan though they are going after a chunk of the country's \$20 billion a year IC market.

The firm will not say how much it hopes to get, and Richard Mann, a TI representative, said: "I don't know how anybody will start about measuring it. I have seen huge figures quoted up to \$700 million a year".

Mann explained the change in philosophy: "We will be expecting revenue from Japan because we have become far more aggressive in pursuing our intellectual property rights."

As a run up to the patent being issued, Texas has spent the last two years making licensing agreements with



*The oldest chip in the world. Did Kilby ever dream of what was to follow?*

Japanese manufacturers. These agreements will not end until the end of next year and it is then that the true impact of the patent will become apparent.

Dick Agnich, senior vice president, said: "TI is pleased that the Japan patent office has issued his very important patent to a US based

company. Our long term programme of seeking patents in Japan has generated a broad, strong intellectual property position there".

TI is based in Dallas but has just announced a new facility at Tsukuba in Japan for researching and developing advanced materials, devices, structures and ICs.

## Solar phone in the dark?

Solar power is coming out of the light as manufacturers become more and more innovative in the way that photovoltaic cells can be used.

So far the main use has been light powered calculators and some 50 million are in use worldwide. But as panels are produced that can operate under very low light conditions, the list of applications continues to grow.

Recent developments have included a garden light that comes on at night using power it has stored up during the day. On a similar principle is a key fob with a small built-in torch for finding the key hole.

And John Gristock, managing director of panel maker Chronar, says that many more applications are under development including door bells and



*John Gristock*

caravan alarms.

One firm is also designing a system for supermarkets where there will be an LCD on the shelf to show the price which will be linked to the computer controlling the tills. Prices can therefore be automatically updated at the till and the shelf at the same time.

For the future Gristock predicts that battery powered products like portable computers could use the cells to extend the battery life. It is also a possibility for portable telephones.

He warns though that some firms may use the advantages of the cell to jack up the price of a product: "The market commands the price and not the product. But for some products that are dearer they avoid the cost of wiring the product in".

## Chips recognise speech

A three-chip speech-recognition set with a claimed 98% success rate has been introduced to the UK by Toshiba. This compares with about 70 to 80% for the firm's existing speech recognition chips.

The 98% figure is based on trials in Japan where the set has been available for about a year. But Nick Milas, applications manager at Toshiba UK, is unwilling to guarantee that figure in the UK until the firm has done some more tests.

He said: "These are all tests in Japan. We haven't checked them fully for the UK." As such he is only considering its use for "noncritical applications".

He added: "We haven't decided on what to do with it yet. It is a careful area, you can put it in the wrong applications. We are looking at car telephones for remote dialling and also remote operation of keyboards."

He fears repeating mistakes made with speech synthesis like the Austin Maestro talking car with which he said "just annoyed people".

The firm is looking at more sensible uses such as in fax machines so the caller can be told that the right fax has been dialled rather than just getting a bleeping noise.

Less successful have been the firm's

record/playback chips which have been in the UK for about six months. The firm has been pushing them hard but so far the only major use has been solid state answer machines, an area that so far has not really taken off.

The idea is that the product links to a DRAM or SRAM and gives the flexibility of a conventional tape recorder without the problem of the tape ageing and quality being reduced. The problem is that, to get a decent quality recording with the chip, the amount of storage time is severely limited.

For example at 32kbit/s using a DRAM, the maximum recording time is only two minutes. This can be extended with good design and lower bit rates, but for most uses it is still not acceptable.

Milas thinks this is about to change: "Over the next six to twelve months there will be a trend towards them."

The firm's push on the playback/record chips is likely to mean that the concentration on the three chip recognition set is likely to be lower than needed and it will probably be some six months before the firm really attacks this market. The set comprises the TMP80C50 cpu and the TC8861 and 8862 recognition chips.

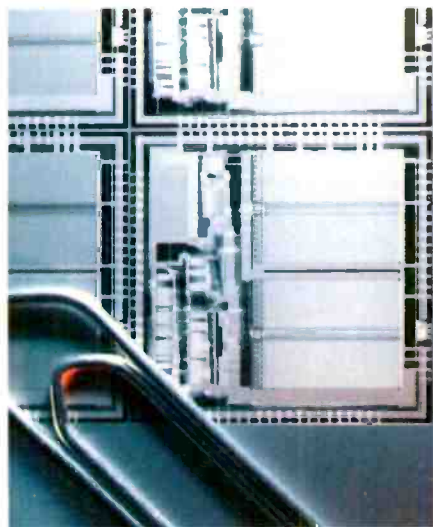
## Massive silicon

ES2 has released details of a 256sq mm chip that was designed for Lund University and at the time was the largest chip ever designed on Silicon Compiler Systems' Genesil toolset. It is also the biggest ES2 chip that the firm is allowed to talk about.

Anne Thomas, ES2's marketing communications executive, said: "We have done larger chips. But the couple that have been done can't be named."

The Lund chip contains 240 000 transistors and runs at 20MHz. It is an ASIC chip and acts as a coprocessor for computers running Ada. It has increased the speed of processing some Ada instructions by 100 fold.

Close on its heels is a 138sq mm asic designed by Sextant Avionique using ES2 Solo 2000 software and cell libraries. It has 130 000 transistors including two multipliers and rom megacells. It is part of a five-channel global positioning system for aircraft navigation.



*ES2 makes custom designs by writing direct on the silicon wafer using electron-beam technology. The firm is therefore less constrained on die sales and more flexible on production quantities.*

## Computing leads inflation

Computer staff have seen their salaries rise 9.7 per cent over the last year, well above the rate of inflation, according to a survey by the National Computing Centre. The survey found that for most jobs, pay rose between 8 and 12 per cent.

One reason for the high rises is that the industry is still suffering from a serious skills shortage. This leads to a high labour turnover as workers flit from company to company in search of ever higher salaries. The NCC says that for the industry "high expected growth rates do not auger well for an end to the shortage".



Sir Bryan Carsberg

## Index linked circuits

British Telecom will no longer be able to raise its prices for private circuits by more than the rate of inflation.

The ban is in the form of an amendment to the BT licence signed by Sir Bryan Carsberg, director general of telecommunications. He announced in October that he intended to control the price of private circuits.

Sir Bryan said: "I have received no objections to the proposed amendment or representations about it. I have therefore made the modifications to BT's licence."

The price increases BT announced in November and which came in to force in December are within the new limitations.

But Sir Bryan warned: "I shall be discussing with BT what further steps can be taken to provide helpful information to users about prospects for future price changes."

# Eprom programming by PC

**S**tratos is a PC-based eprom programmer which consists of a half-size plug-in card for a PC, connected to the external programmer module by a ribbon cable. The software is entirely menu-driven, with a thoughtfully laid-out main screen menu and context-sensitive help displays. The hardware is compatible with a PC-XT or AT bus and the software requires PC-DOS or MS-DOS version 2.0 or later, and at least 512K of ram. Extensive use is made of surface-mount technology in the design and construction of card.

## Installation

This takes about five minutes and consists of inserting the card inside the PC and copying the contents of the floppy disk provided onto the hard disk of the

Fi Agladious reviews the Stratos PC plug-in, which supports over 230 devices from 26 manufacturers and which will program devices of up to 1Mbyte

computer (floppy disk operation is possible). The I/O address of the card can be altered by jumper selection.

## Operation

Stratos programmer accommodates 24, 28 and 32-pin devices; it uses 128K of the computer's memory and is capable of programming devices up to 1Mbyte. It supports over 230 devices from 26 manufacturers, including AMD, Hitachi, NEC and Texas Instruments, but not the full range of devices covered by more expensive programmers.

Two programming formats are possible with Stratos: the Intellec and the Motorola S-Rec (Exorciser) formats.

The Intellec format has the following structure:

- a start code, which is a colon;
- the number of data bytes in the record in hexadecimal;
- the address of the first byte of data in the record;
- the record types: 00 for a data record and 01 for the end record;
- the data bytes;
- the checksum of the record.

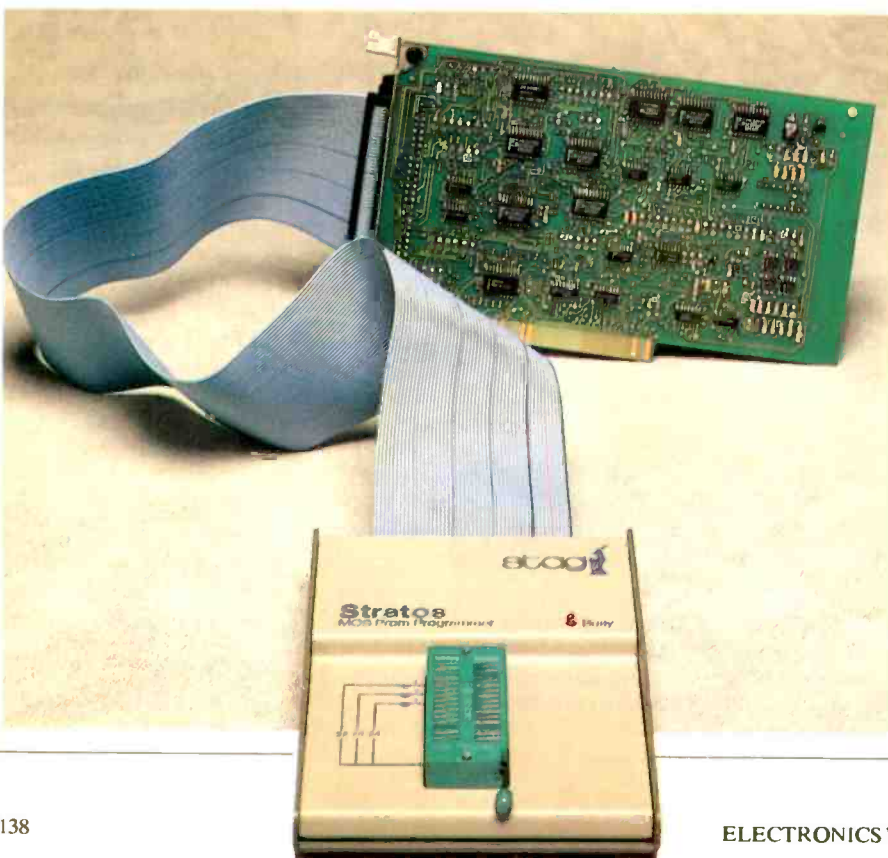
For a single record with 16 bytes starting at address zero, the format would be as in Fig. 1.

The S-Rec standard takes the following format:

- a start code, which is a capital S;
- the record type: 1 for a data record, and 9 for the end record;
- the number of bytes in the record including the address data and the checksum;
- the address of the first byte and data in the record;
- the data bytes;
- the checksum of the record.

## Programming a device

The major step in programming a device involves creating the Intellec or



S-Rec format file, which is carried out independently of the programmer software as with all other programmers. However, the benefits are revealed on transfer of the file contents to the device to be programmed. Stratos effects this in two intuitive stages: "Load ram with file" and "Program device". There is no need to set data rates, make up leads or remember obscure commands, as with conventional programmers.

In addition, programming times are greatly reduced because the programming mode is directly linked to the computer: the programming time for a 32K x 8 eeprom was less than three minutes using an old IBM-AT.

### Other device functions

Reading the contents of a device into the system ram and then into a file is the converse of the above operation and is also accomplished with only two functions: "Load ram from device" and "Store ram into file". The format of the stored file conforms to one of the two formats described earlier. Stratos also has a user-friendly verification

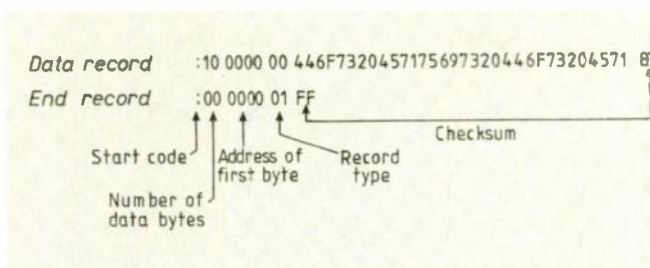


Fig. 1. The Intellec format

function which performs a comparison between the contents of a device and those of a file; the software produces a list of the pertinent discrepancies and allows the user to scroll through these at will. A "blank check device" function is also provided.

### Other features

As well as these file and device functions, Stratos has a host of ram editing functions. This is probably one of its major strengths because the PC platform allows examination of ram contents on a page-by-page basis to see major trends, patterns or mistakes. There are also powerful block copy,

delete and insert functions for data-oriented operations. To aid in the modification of global ram contents, logic functions such as And, Or and Complement, nibble and byte-swapping functions and ram-filling capabilities are provided.

### Conclusions

The Stratos programmer, at £249 excluding VAT and carriage, is excellent value for money. The colour menus make it easy to use and this user-friendliness is further enhanced by the excellent Help menu. My only complaint about the system is the lack of a manual which, although not absolutely necessary, particularly if one is intimately familiar with the Intellec and S-Rec formats, is nevertheless of great psychological importance. A printed device list also appears to be a short-sighted omission.

Stratos is made by Stag Microsystems Ltd, Marfield, Welwyn Garden City, Hertfordshire, AL7 1JT. Tel: 0707 332148.

## The Archer Z80 SBC

The SDS ARCHER – The Z80 based single board computer chosen by professionals and OEM users.

- ★ Top quality board with 4 parallel and 2 serial ports, counter-timers, power-fail interrupt, watchdog timer, EPROM & battery backed RAM.
- ★ **OPTIONS:** on board power supply, smart case, ROMable BASIC, Debug Monitor, wide range of I/O & memory extension cards.

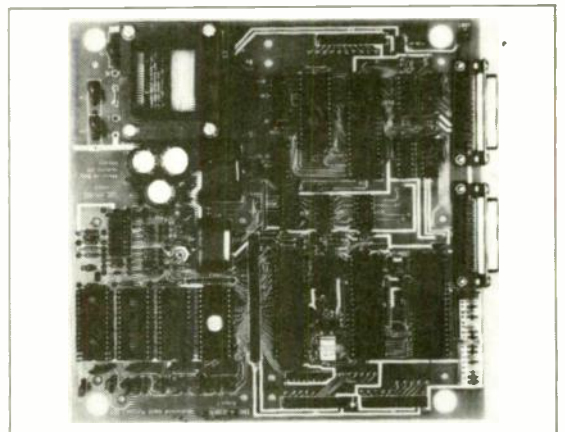
CIRCLE NO. 109 ON REPLY CARD

## The Bowman 68000 SBC

The SDS BOWMAN – The 68000 based single board computer for advanced high speed applications.

- ★ Extended double Eurocard with 2 parallel & 2 serial ports, battery backed CMOS RAM, EPROM, 2 counter-timers, watchdog timer, powerfail interrupt, & an optional zero wait state half megabyte D-RAM.
- ★ Extended width versions with on board power supply and case.

CIRCLE NO. 126 ON REPLY CARD



## Sherwood Data Systems Ltd

Unit 6, York Way, Cressex Industrial Estate, High Wycombe, Bucks HP12 3PY. Tel: (0494) 464264

## Sinewave sweep generator

All that is needed to make a sweep generator from Precision Monolithic's SSM2044 four-pole, voltage-controlled low-pass filter is a sawtooth waveform with amplitude of 180mVp-p. This is provided by the 555 oscillator (IC<sub>1</sub>). The SSM2044 (IC<sub>4</sub>) has a voltage-controlled cut-off frequency and current-controlled Q.

As the Q is increased, the response of the filter will have a large peak immediately below cutoff and, if the Q is increased far enough, will oscillate. IC<sub>4</sub> oscillates stably with a constant amplitude across the full 20Hz to 20kHz audio range. An exponential amplifier at the frequency-control input gives a voltage-to-frequency relationship of 18mV/octave. With the values shown, +90mV corresponds to 20Hz and -90mV to 20kHz.

The ±7.5V supplies are generated by resistors R<sub>1</sub> and R<sub>2</sub> and zener diodes

D<sub>1</sub> and D<sub>2</sub> and decoupled by capacitors C<sub>1</sub> and C<sub>2</sub>. LM337 and LM317 type regulators can be used.

Tr<sub>1</sub> produces 3.8V across R<sub>3</sub>, charging the timing capacitor C<sub>3</sub> with a constant current. This produces a linear ramp and therefore an exponential frequency sweep. The flyback part of the waveform is not critical, so a resistor is used to set the timing. Reasonably large currents flow when the timing capacitor is discharged and large decoupling capacitors are needed for IC<sub>1</sub>.

Threshold voltages of IC<sub>1</sub> are  $\frac{1}{3}V_{cc}$  and  $\frac{2}{3}V_{cc}$ , so the sawtooth produced has a voltage swing from -2.5 to +2.5V. This is buffered by IC<sub>2</sub> and the output used to drive the X input of the oscilloscope or plotter.

Ian Benton  
Ilkeston  
Derbyshire

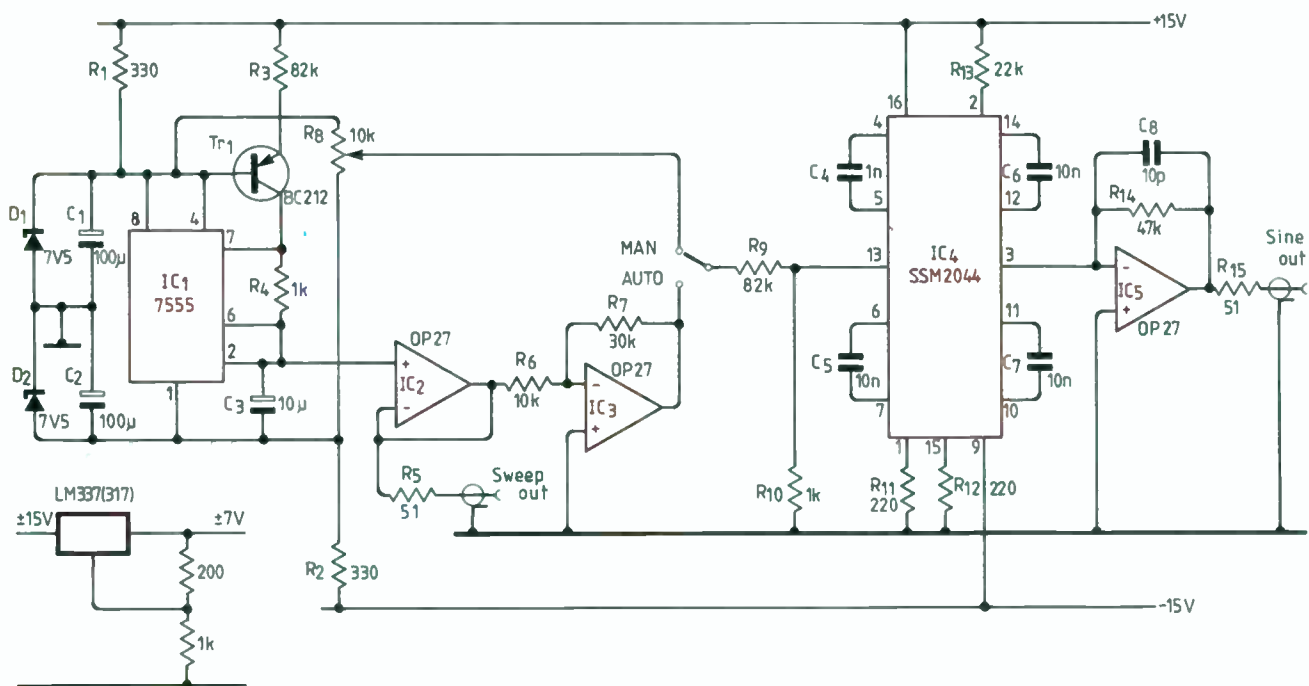
## Digital input audio sector

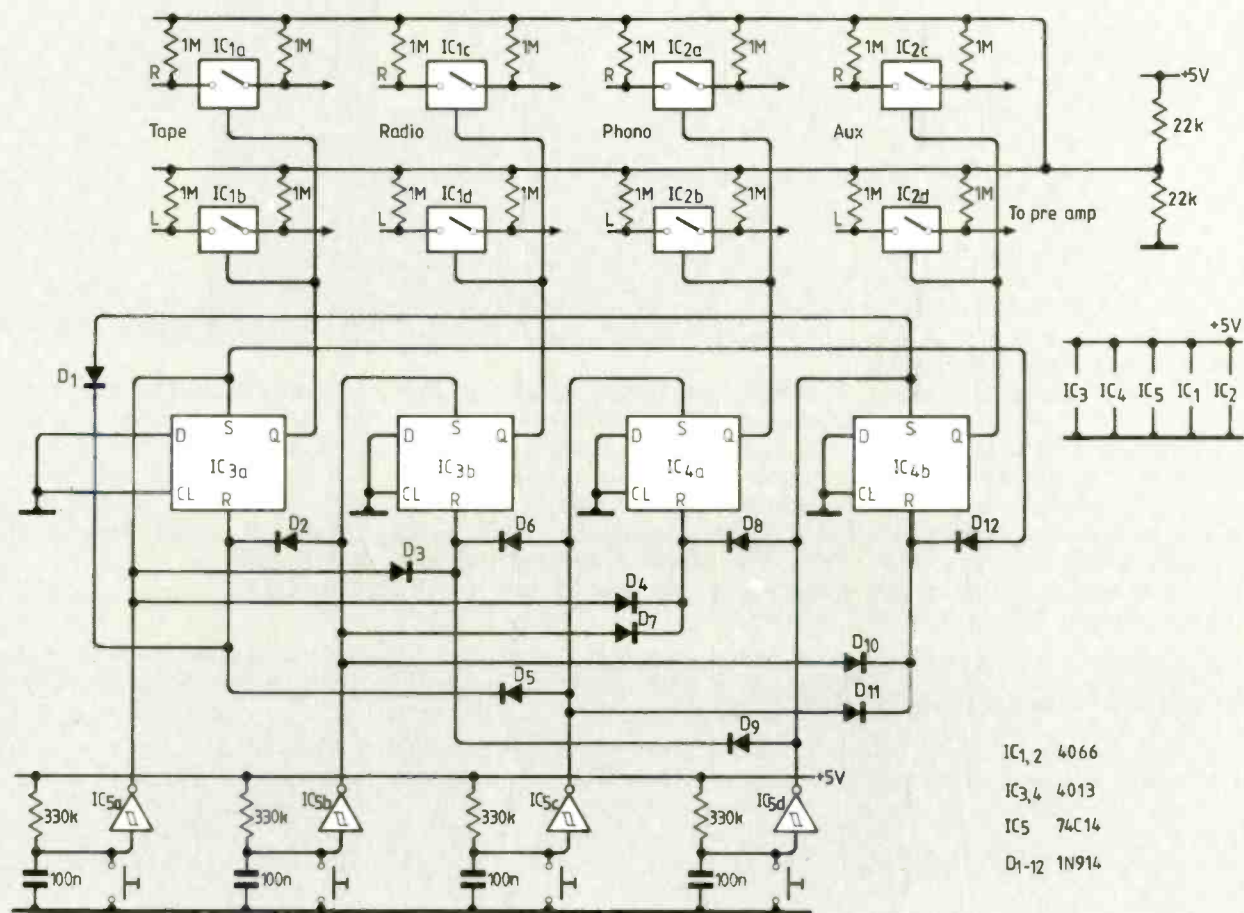
Most high-quality amplifiers use four-way switches to change the input source to the amplifier, but these switches can get dirty and become faulty, causing noise. This circuit uses digital techniques to replace the switches with c-mos 4066 analogue switches.

Four momentary 'on' push switches replace the four-way equivalents; each has an inverting Schmitt gate to produce debouncing. Outputs are fed to four D-type flip-flops connected in direct mode.

When a switch is pressed, the output of the inverting gate sets the output of the corresponding flip-flop high and resets all the others low. If the same switch is pressed again, nothing further happens. Hence only one flip-flop is high at any time.

The outputs are connected to the control inputs of two c-mos analogue





switches, allowing the wanted signals to be fed to the preamp. Each side of each c-mos switch is biased at half  $V_{cc}$  to allow maximum signal feedthrough with minimum distortion.

Diodes  $D_1$  to  $D_{12}$  act as Or gates and also prevent incorrect outputs; for example two flip-flop outputs high. Current consumption should be no more than 7mA.

Darren Yates  
French's Forest  
New South Wales

## Frequency doubler

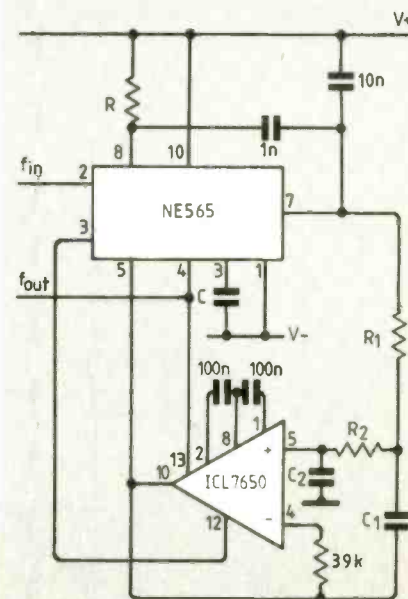
When the loop of a PLL is broken between the VCO and phase comparator and the fundamental of the  $\times 2$  divided VCO frequency-locked to the input frequency, the VCO is running at double the input frequency. This circuit uses the internal  $\times 2$  divider of the

chopper-stabilized op-amp of the ICL7650. It has a divider, amplifier and low-pass filter in one integrated block.

The op-amp is inserted as a low-pass filter to remove higher components of the sum frequency components. The cut-off frequency of the low-pass filter (given by  $f_o = 1/(2\pi \sqrt{C_1 C_2 R_1 R_2})$ ) can be chosen according to the application.

Without the circuit, in the frequency multiplication the output of the phase comparator contains sum and difference frequency components. The difference component is DC and drives the VCO to keep the PLL in lock. The sum frequency components, of which the fundamental is twice the frequency of the input signal, if not well filtered will induce incidental FM on the VCO output.

Kamil Kraus  
Rokycany  
Czechoslovakia



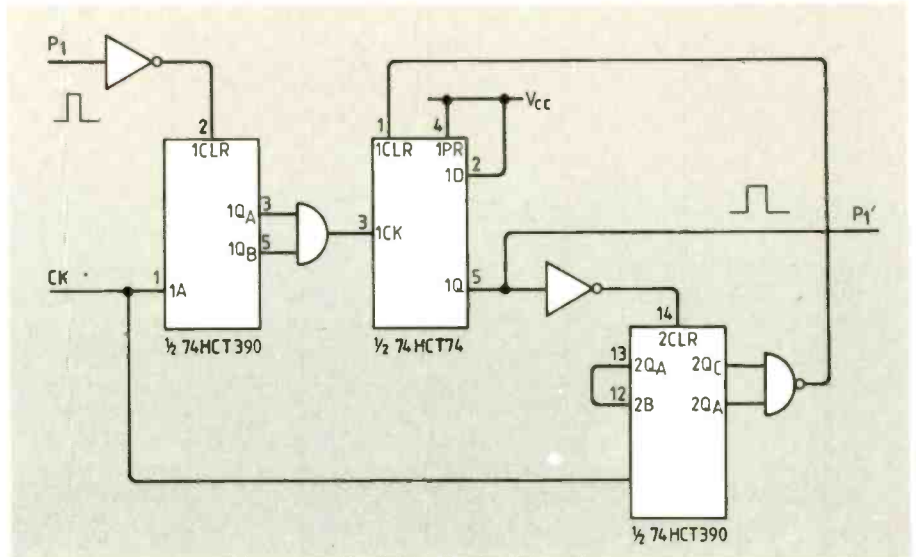
## CIRCUIT IDEAS

### Cascadable clocked pulse delay/lengthen circuit

Buffers and amplifiers usually add phase delay to analogue signals, which can be a problem for A-to-D converters if the start-conversion pulse has been generated without taking this into account. This circuit delays the pulse by a variable amount and varies the length of the pulse if required by multiples of the system clock frequency.

The only limitation is that the pulse cannot be delayed by longer than the original pulse length with only one stage. But cascading the two stages, lengthening the pulse with the first and delaying with the second, overcomes this.

The inverted original pulse is applied to the clear input of the first half of a BCD counter (or binary) which, when it goes low, enables the counter which is clocked by the system clock. Any combination of outputs can be Anded to provide a suitable delay subject to



the limitation already mentioned. The delay should be not more than ten clock cycles for a BCD counter.

After the selected number of clock pulses (three in this case), the flip-flop is triggered, causing the output 1Q to rise. This output is also inverted and applied to the second half of the counter clear input. This then begins

counting, clocked by the system clock, for the selected number of clock cycles (five here). When this is up, the flip-flop is cleared and the output again falls. P<sub>1</sub> will have fallen again and the circuit will not be triggered until the next P<sub>1</sub> pulse.

Peter Turner  
York

### Modified low-drop regulator

There are two problems with conventional low-drop regulators. First, the overload characteristic is undefined and, secondly, the series-pass p-n-p transistor is costly in high I<sub>c</sub>, high h<sub>FE</sub> ranges.

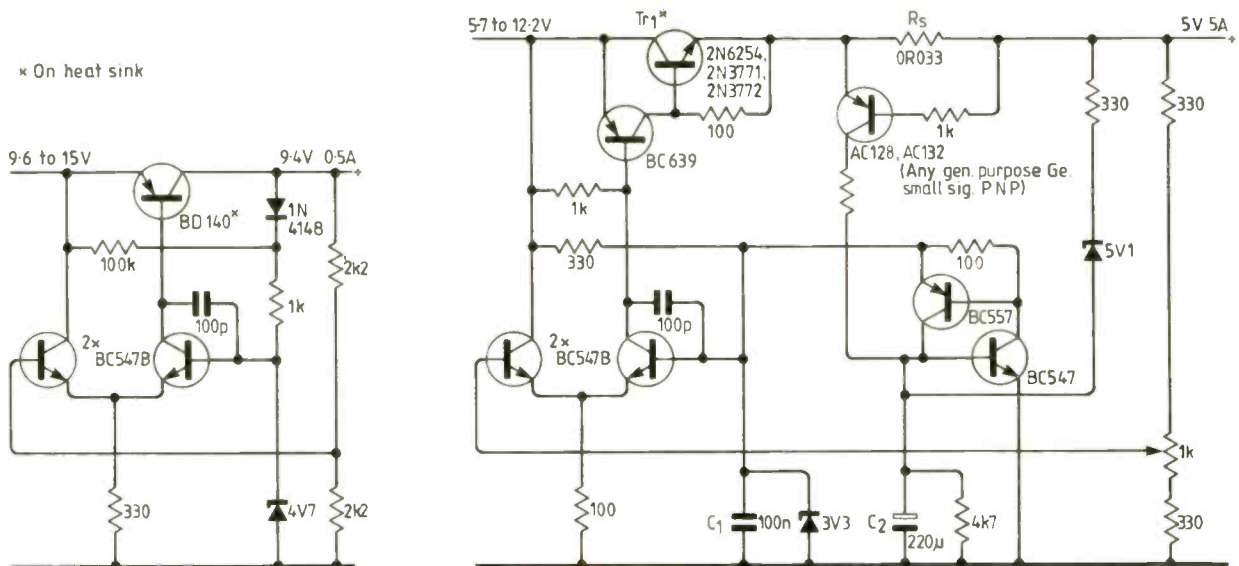
But the circuit can be modified for higher currents and incorporate defined overvoltage and overcurrent protections at the output. The I<sub>o</sub> is increased from 0.5 to 5A and can be

increased further with a different Tr<sub>1</sub>, yet the drop is less than 0.6V when the input voltage is minimum.

A P-channel mosfet could be used as an alternative series pass device. The minimum stabiliser circuit input voltage would then be in the order of six volts using the first circuit arrangement. This allows for enhancement turn-on and headroom for the control transis-

The overvoltage trigger point is around 5.6V at output and the transient overload characteristics can be stretched by increasing the value of C<sub>2</sub>. The overvoltage and overload protections act by sinking the output until the power is turned off and turned on again.

Anadish Pal  
Pitampura  
Delhi, India





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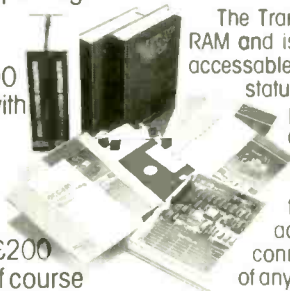
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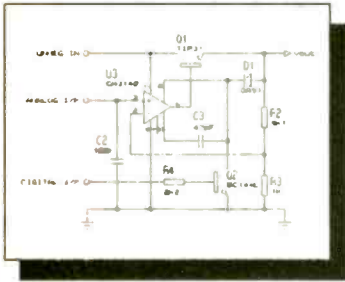
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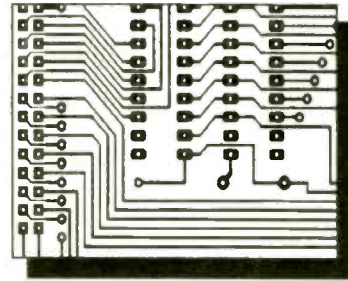
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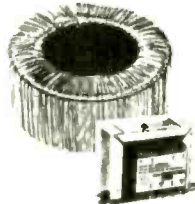


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50	10.96	9.86	7.23	6.85	6.19	5.75	5.48
60	11.28	10.15	7.44	7.05	6.37	5.92	5.64
80	11.88	10.69	7.84	7.42	6.71	6.24	5.94
100	12.88	11.59	8.50	8.05	7.28	6.76	6.44
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625	30.06	27.05	19.84	18.79	16.98	15.78	15.03
750	38.42	34.58	25.36	24.01	21.71	20.17	19.21
800	43.96	39.56	29.01	27.48	24.84	23.08	21.98
1000	53.54	48.19	35.34	33.46	30.25	28.11	26.77
1200	59.08	53.17	38.99	36.92	33.38	31.02	29.54
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EB91	0.60	EL95	1.80	QOV03/20A	27.50	5Z4GT	1.80	6J5GT	1.90	19H5	38.00
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EBF80	0.75	EL822	11.50	SP61	3.20	6AG5	0.60	6J56C	9.15	25L6GT	1.90
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ECF82	1.25	GZ32	2.80	UL84	1.50	6AX5GT	1.30	6SK7	1.85	931A*	26.80
ECF82	1.25	GZ32	2.80	UL84	1.50	6BA6	1.75	6SL7GT	4.35	954	1.10
ECH42	1.65	GZ34	2.45	UM80	2.30	6BA6*	2.20	6SN7GT	4.35	955	1.10
ECH81	1.25	GZ34*	6.00	UY82	1.10	6BE6	1.75	6S07	0.95	956	1.20
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ECL85	0.95	ML6	3.20	VR150/30*	4.95	6B07A	3.95	6X5GT	0.75	6080*	7.30
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## ACTIVE

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**C-mos production process.** ECPD-12 is the name of ES2's 1.2 micron dual-layer metal c-mos process, developed to offer die-size reductions for manufacturers wanting to integrate high-complexity designs on a single chip in excess of 100mm sq. Asic designs prototypes by ES2 can be transferred for manufacture by Philips. European Silicon Structures, 0344 525252.

**High density c-mos.** 26 000 and 47 000 gates with over 70% utilization are offered by Motorola's HDC026 and 027 high-density c-mos micron arrays. The channelless sea-of-gates architecture gives 300ps delays, with a fan-out of 2. The 026 has 168 i/o pins and the 047, 212. Slew-rate control macros provide two choices of output slew rate. Motorola, from distributors.

### Data converters.

**Digital to analogue.** The DAC-8228 has a voltage output and is a direct replacement for Celdis' AD7528/7628. It is a single-chip dual 8-bit c-mos device designed for outputs of 0V to +10V. Features include two integral output DACs, matched to 0.1%; 8-bit endpoint linearity, a write time of 50ns; and low power consumption. Available in 20-pin Cerdip and plastic packages. Celdis, 0734 585171.

### Development and evaluation

**State machine.** The 125MHz CY7C361 high-speed state machine announced by Ambar Cascom allows EPLD-based logic design for systems with clock rates up to 66MHz. It incorporates an on-board clock doubler. Power consumption is 700mW. New PLD architecture has been used to improve performance over other PLD-based state machines. Ambar Cascom, 0296 434141.

**In-circuit emulator.** Reduced program download time – typically 4s for a 16K object and symbol file – is one of the advantages of Nohau's 68HC11 emulator. Nohau claims this is the first emulator to be PC-resistant rather than stand-alone. High sample rate, through eradication of the usual serial link, is another plus. Nohau UK, 0962 733140.

### Discrete active devices

**Barrier diodes.** Hi-rel 3-5 GaAs planar doped diodes, obtainable from Marconi, offer high pulse burn-out resistance, low local-oscillator drive requirements and high tangential sensitivity, together with improved I/I side-band noise performance. These combine to give good detection sensitivity and temperature stability. Marconi Electronic Devices, 0522 500500.

### High performance semiconductors.

Lower noise, better linearity, higher transition frequencies or reduced capacitance are the goals of Siemens' latest RF Silicon transistors. Its BFQ 82 noise level is less than 1.6dB (at 800MHz) with a gain of 17dB (at 1GHz) while its BAT 64 Schottky diode draws 200mA forward current, and has an overall capacitance of 6pF. Siemens, 0932 752323.

**Mesfet for telecomms.** Toshiba has announced a new mesfet designed to produce extra power for high-frequency operations. JS8856-AS provides a power output of 33.5dBm at 14.5GHz with a gain of

5.5dB. The 100micron device has a thermal resistance of 9°C/W. Dimensions are 2.1mm by 0.53mm and Toshiba has increased the thickness of the chip to 70micron. Toshiba Electronics (UK), 0276 694600.

### General microprocessors

**STD multiprocessing.** The Ziatech ZT8832 single-board STDbus multiprocessing computer with dos extension can enhance performance, control, modularity and development facilities within control applications. The 8MHz V40 micro ICP uses its own resources, not the system's. 300K on-board memory. SBX expansion socket, three parallel ports, two serial ports. Optional maths co-processor. Wordsworth Technology, 0732 866988.

### Interfaces

**Multi-serial port tester.** Async4-II is a short-slot, multi-serial, 4-port card for use with PC/XT/AT and compatibles. Supplied with 4-way 25-pin D connectors and Accent MS-DOS and PC-DOS support software, it allows simple testing of multi-serial port systems. List price £295. Accent Computers,

**Parallel DMA link.** Ikon 10092 card provides a high-speed parallel DMA port between Versatec or Centronics-type hard-copy devices and IBM compatibles. It can be used in any AT-compatible or with a peripheral device adapter such as that provided with Apollo DN3000/4000 workstations. Taking up a single AT slot, it allows a 6MHz PC/AT system to transfer data at up to 425 kb/s. GMT Electronic Systems, 0372 373603.

**DMA parallel interface.** Compatible with DE DRV11-WA, Q-bus, MicroCas II and 18-bit and 22-bit backplanes, the GT370 DMA board features 16 bit input and output ports, used to transfer parallel data to and from the Q-bus under program control or DMA. For heavily driven i/o, the unit contains a jumper throttle allowing selectable interleaving on and off the bus. Lighthouse Electronics, 0825 68849.

**I/o controller.** The IO 186/070 analogue and digital i/o board for Multibus II systems manufactured by Concurrent Technologies is available through Rapid Silicon. It has a 10MHz 80186 CPU, six analogue outputs (employing 12-bit D-to-A converters and amplifiers), 16 single-ended or eight differential analogue inputs (0 to +10V and 0 to -10V) and 48 digital i/o lines. Rapid Silicon, 0494 442266.

### Linear integrated circuits

**Op-amp.** AD843 is said to be the fastest fet-input monolithic unit on the market. 135ns settling time of 10V steps to within ±0.01%. 34 MHz gain-bandwidth. The manufacturer also claims low costs and low power use as two of its features. Available in five temperature performance grades and also to Mil-Std-883B. Analog Devices, 0932 253320.

**Video amplifier.** EL2030 is a 120MHz 3dB bandwidth amplifier intended for line driver applications, optimized for gains between +10 and -10. It is pin-compatible with the Elantec EL2020 but with a slew rate of 2000V/s, a gain differential phase of 0.01 degrees and a current drive capability of 65mA. Operating from ±15V, it will drive ±10V into 100 ohms at 90MHz. Available in 8-pin dip, 14 pin cerdip, 20 pin SOL and 20 pad LCC. Microelectronics Technology, 0844 278781.

**Operational amplifier.** Optimized for a gain of 5, the Harris HA-2548 from Thame

Components has a gain/bandwidth product of 150MHz, a slew rate of 120V/, a loop gain of 130dB and 300 V offset voltage. Settling time is 200ns to 0.01% (10V step). Available from stock in 8-pin cerdip and 8-pin can packages. Thame Components, 0344 261188.

### Memory

**C-mos eeprom.** Seiko Epson have introduced a 512-bit device working at 0.9V. The SPM28C51 series is available in 8-pin SOP or DIP packages. They operate from 0.9V to 5.5V at the read stage with a supply current down to 40µA maximum at 1.5V. Design is 10 000 erase/write cycles per bit and a ten-year bit-retention time. Hero Electronics, 0525 405015.

### Optical devices

**Laser light sources.** Two ruggedized 3M-Photodyne sources are now available from Lambda. Both are stabilized single-mode sources. Model 7160 produces emission at 1300nm. 7170 emits at 1550nm. Units are portable – weighing 12lbs – held in water-tight, heavy-duty militarized cases. Power is from internal 12V batteries. Features include adjustable level setting. Lambda Photometrics, 05827 64334.

**Triac optocoupler.** Siemens says its IL 428 is the first optocoupled triac delivering 2A at 55°C without additional cooling. Sensitivity is said to be so high that an input of less than 8mA (typically 4mA) is enough to switch up to 2A. A safety factor greater than 2 is promised with operation on 230V AC systems. Siemens, 0932 752323.

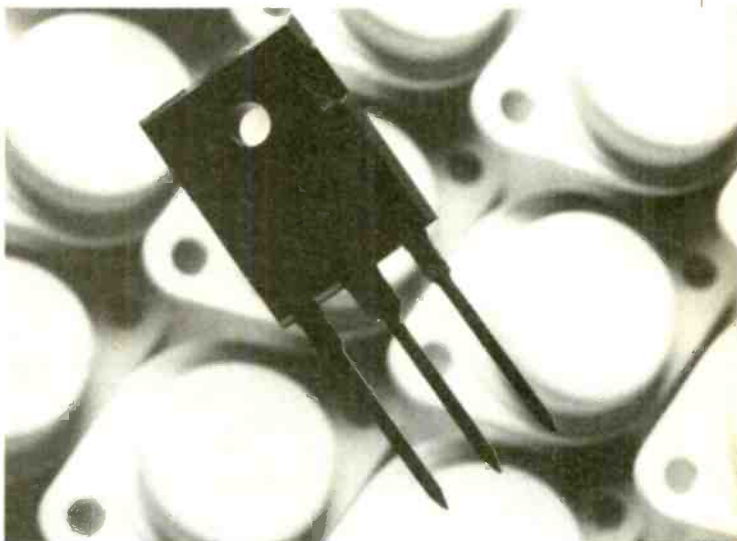
### Oscillators and crystals

**Miniature oscillator.** The Ball-Efratom FRS time base oscillator, available from Racal-Dana, offers long term accuracy of 1 in 10<sup>9</sup> per year. Its dimensions are 2 × 3 × 4in and it may be installed directly in instruments or systems. The unit uses 10W at 24V DC and will warm up to the above accuracy in 6 min. Standard output is a 10MHz sine wave delivering 0.5V RMS into 50 ohms, with options. Racal-Dana, 0703 843265.

### Power semiconductors

**Easy mounting transistors.** Low on-resistance transistors in an industrial plastic package offering easier mounting can now be obtained from Siliconix. Nine devices are included in the range, based on the popular TO-220 package, and they do not suffer from the size disadvantages of the larger TO-3 packages. The devices also run cooler with greater reliability. Siliconix, 0635 30905.

Low-on resistance power mosfets from Siliconix, now in TO-247.



## PASSIVE

### Passive components

**Miniature potentiometer.** 10mm square, in over 750 000 combinations, all with conductive plastic elements to ensure low noise, the miniature Wilbrecht Electronics potentiometer can now be obtained from Radiatron. The model 400 has eight standard tapers and can be supplied in single or dual-gang configurations. It is sealed for wave soldering. Radiatron Components, 0276 26466.

**High frequency capacitors.** The equivalent series resistance of Siemens' B45177 (axial lead) and B45187 (radial lead) tantalum electrolytic capacitors has been cut by over 50%. It now ranges between 45 and 330 milliohms to meet the requirements

of switched-mode power supplies. Capacitance values are 4.7µF to 330µF with current ratings of 1.1A to 4.6A RMS. Siemens, 0932 752323.

### Connectors and cabling

**Cable ends.** Contelec has extended its range of insulated cable ends to include types for use with stranded conductors from 0.25 up to 70mm<sup>2</sup> cross section. Standard and long versions can be supplied in all sizes and short and intermediate versions are available for most commonly used sizes of cables. Contelec Supplies, 0902 366556.

**Cables and hoods.** Thomas & Betts 300-XX series fully screened flat and round cables and associated hoods is being offered by

## NEW PRODUCTS CLASSIFIED

Highland Distribution. Cable used is 28AWG stranded. Screening is with PVC-coated aluminium tape with additional braiding of tinned copper wire. External coating is flexible PVC. Eight versions are available. Highland Electronics, 0444 245021.

### Displays

**Rackable monitors.** Use in hostile environments is the aim of this range of 19in rack-mounting units, supporting all the common graphics standards including EGA and VGA, in colour and monochrome. All are encased in nickel-plated mild steel with a 6mm-thick Perspex screen to protect the monitor. Prices start at £480 for the mono version. Blue Chip Technology, 0244 520222.

**Small VGA colour monitor.** Nine-inch VGA screen units for mains use with a maximum current consumption of 0.7A are available from Components Bureau. The Sony Trinitron tube used has a short-persistence B22 phosphor, with high resolution to 640x400 on a display area of 140x100mm with a dot pitch of 0.26mm. Dimensions are 164x210x310mm. 5.2kg. Components Bureau, 0223 214949.

**Led displays.** A range of single-digit, seven-segment, numeric led displays from 7.62mm to 177.8mm, manufactured by Everlight Electronics, can now be obtained from HB Electronics. Colours include a choice of reds, green, yellow and orange. Each is equipped with a decimal point. HB Electronics, 0204 25544.

**Colour terminal.** ELF colour 14E terminal has VT220/VT320 compatibility with additional VT52, VT100, M2200 and Viewdata emulations as standard. All keys are programmable. Its high resolution screen has 0.31mm dot pitch and offers 16 colours. Graphics and character sets can be defined. Easydata says it is designed to be a low-cost display, DEC compatible. Monotype Easydata, 0784 244277.

### Filters

**Hex filter.** MA6882 hex filter designed to

consolidate filtering requirements in the DC-8kHz range in multi-channel analogue signals systems. Two 7th order low-pass filters, two 6th order band-pass filters and two 6th order notch filters are included on one monolithic c-mos chip. All filters include anti-aliasing circuits. Marconi Electronic Devices, 0522 500500.

**Hardware**

### Hardware

**Eurocard backplanes.** Double-sided uncommitted backplanes with four voltage rails, and jumper pins to allow any signal line to be committed to any voltage rail are now part of the BICC-Vero Eurocard range. Power connections can be M3 studs or 6.33mm Faston tabs. Five sizes are available. Bicc-Vero, 0703 266300.

### Instrumentation

**Power surges.** Elgal's modular system for testing power surges can now be obtained from Dielec. The EM101A is a transient generator system; 1044A series plug-in units provide test wave forms simulating lightning, 1011A and 1012A EXP series provide powerful pulses with fast rise time and exponential decay; 1020 provides a damped sinusoid. Dielec, 0793 783137.

**Function generator.** The 5MHz GFG-8050 from Flight Electronics combines quality construction with low cost. The unit's frequency range spans 0.5Hz to 5MHz and it has multi-function output, sweep and gate burst operation. Wave-forms include sine, triangle, square, pulse and ramp. There are six other units in the range. Flight Electronics, 0703 227721.

**Digital storage oscilloscope.** Grundig's SO 50 and SO 100 oscilloscopes have digital and analogue bandwidths of 50MHz and 100MHz respectively. Scanning frequencies up to 40M samples/s with storage capacities up to 4K produce optimum recording of signals in the digital mode. Real time sampling or sequential sampling can be selected. Grundig Electronic, (W. Ger.) 9 11 73 30.



Grundig's SO 100 100MHz digital storage oscilloscope.

**Battery dual trace oscilloscope.** Hitachi's V209 mini portable unit is now available from IR Group. The DC-20MHz bandwidth instrument measures 215x110x350mm, weighs 5.3kg, and offers a sensitivity of 1mV/div at 10MHz and sweep times of 50ns/div. It has a built-in tv sync separation circuit with selectable tv-v and tv-h modes. IR Group, 0753 580000.

**Digital phase meter.** The Feedback type DPM609 will display the difference in degrees between two signals of the same frequency. 3.5 digit fluorescent display will show 0° to 180° in 0.1° steps. Its frequency range is 10Hz to 100kHz. Two symmetrical channels accept signals from 10mV to 10V RMS "sine" or 1V to 30Vpk-pk for "logic" waveforms. Resolution 0.1°. STC Instruments, 0279 641641.

### Literature

**Power supplies.** The XP 1990 catalogue is now available, with 76 pages covering linear supplies, switched mode supplies, eurocassette supplies, DC-DC converters and laboratory burn-in supplies. Companies represented include Computer Products, Danica, Elco, Electronics Measurements, HC Power, International Power and Schafer Electronics. XP, 0734 508179.

### Materials

**Ferrite cores.** Steward's soft magnetic type 28 material is the basis for a range of ferrite cores now offered by Ramp Electronics. It is particularly suitable where applications involve frequencies of 1kHz or greater. Cores may be specified to meet intended functions of wound components. Configurations include E or U shapes for power applications. Ramp Electronics, 0703 260161.

### Production equipment

**Removal of surface-mount components.** CPE's system 1000 portable rework station can desolder and resolder using directed hot air blowers. Though designed for surface-mount components it can also remove 0.3in (6-20-pin), 0.4in (22-pin), 0.6in (24-pin) DIL components and now PGAs. Boards up to 24x16in can be accommodated. Circuit Plating Equipment, 0635 33656.

**Component preformer.** French-manufactured Loupot CK machine, introduced to the UK by John Minister, is suitable for performing axial components at

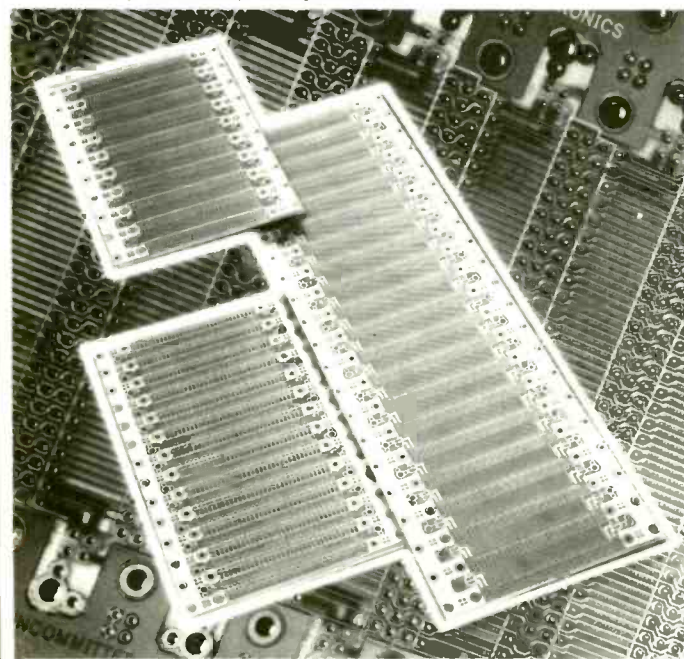
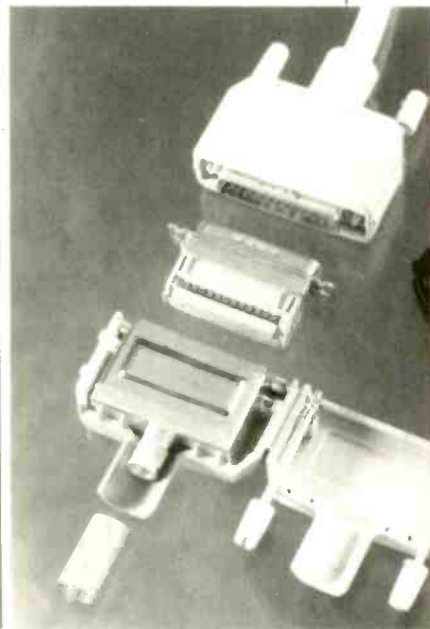
up to 20,000/h – ideal for small to medium batch runs. It can handle most bandoliered forms and cutting and banding is adjustable within 0.1mm. Compact design produces easy changeover and low set up times. John Minister Automation, 0303 568167.

**Wire twister.** Rush's model WT20 is an improved version of its WT12 and incorporates an LCD pre-settable read-out and special wire-clamping mechanism. It is particularly useful for twisted pairs and can twist two or more wires, up to 16AWG, of any length up to a speed of five twists/s. Rush Wire Strippers, 0264 51347.

### Power supplies

**Compact supply.** Acdc's JF201 2000W switchable power supply, from Astec UK, provides 2 or 5V DC output at 400A, with other outputs of 12, 15, 24, 28 and 48V DC. Dimensions are 5x8x10in – a power

Connectors and hoods for Thomas and Betts' flat and round cable.



## NEW PRODUCTS CLASSIFIED

density of  $5W/in^3$ . 208/230V AC or 300V DC input with full output at typical efficiencies of 80%. Switching is at 100kHz. Two forward converters are used. Astec UK, 0246 455946.

**Capacitor charging unit.** Series 5000 modular power supply is a low-profile 19in rack-mount with a charging rate of 600J/s. Voltages are 1, 2.5, 5, 10, 20 and 30kV with regulation and resolution figures of 0.5%. Maximum repetition rate is 10 pulses/s, though other voltages and rates are available. Hartley Measurements, 0752 344606.

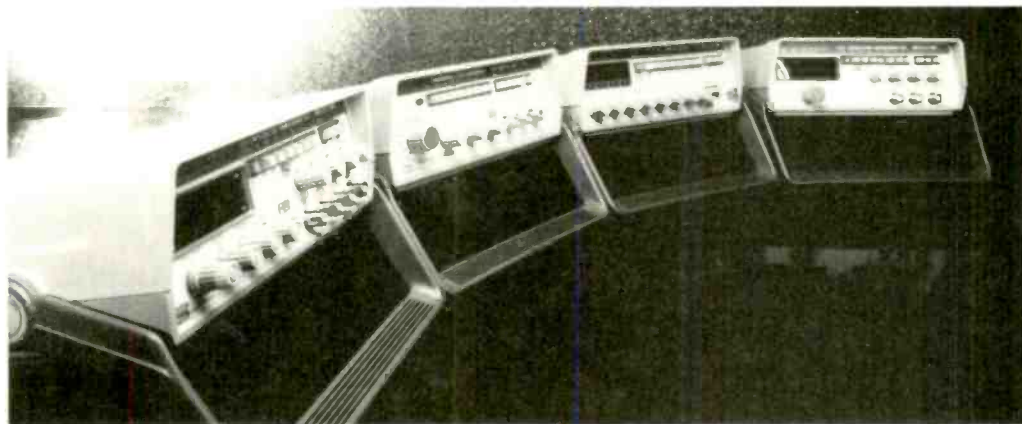
**Selectable power.** Astec MS series supplies from Thame Power are rated at 1200W and can provide any combination of 5, 12, 15, 24 or 48V outputs. Configurable AMPSS modules can be factory or customer selected for particular requirements. Overall efficiency is 75%, with a 500kHz switching frequency. Dimensions are  $8 \times 5 \times 1$  in. Thame Power, 0494 442266.

**Dual laboratory power supplies.** The Twinpack power supply 4000/2 from Weir gives a total of 120W from two identical, isolated, 0-30V, 0-2A sections. True constant current/constant voltage operation and output protection diodes allow series/parallel connection, also giving 0-30V, 0-4A and 0-60V, 0-2A. Simultaneous monitoring of each rail is possible. Weir Electronics, 0243 865991.

### Switches and relays

**Sub-miniature switches.** LIMA A6 series switches are designed for surface mounting and are fully sealed to allow wave and flow soldering. Resistive ratings with silver contacts are 250V AC at 2A, 125V AC at 5A. Gold contacts give 5V AC/DC and 1.0 A minimum of 20V AC/DC at 0.4VA maximum. Insulation resistance is at least 1000M. Electric strength is 1kV for 1 minute. Arrow-Hart (Europe), 0752 701155.

**Light load relays.** Standard and high-sensitivity relays have been made available by Devlin in its M3 series for PCB mounting.



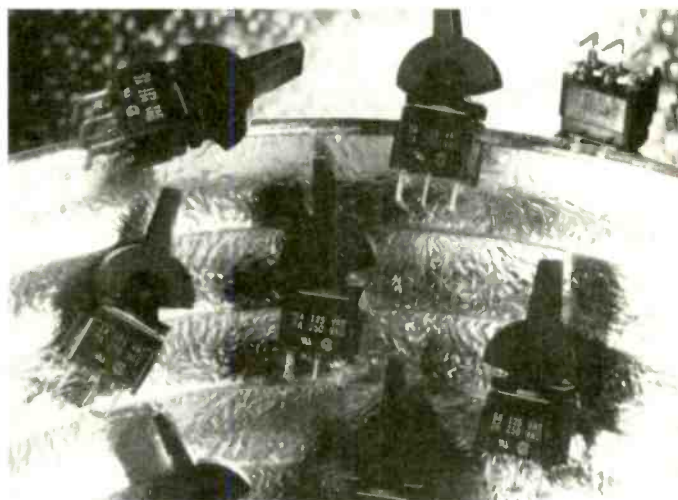
Function generators from Flight Electronics.

With a resistive load the maximum switching current is 1A AC/DC. Maximum switching power is 30W DC, 60VA AC with maximum switching voltage of 60V DC, 120V AC. Devlin Electronics, 0256 467367.

**SIL relays** A relay 3.7mm wide, 15.1mm long and 6.6mm high, claimed to be the smallest currently available, has been introduced by Pickering. Its series 109 requires half the board area needed by some other SIL relays. Switches are rated at 10W 200V and 0.5A maximum. 5V, 500 and 12V 1000 coils are available. Pickering Electronics, 0255 428141.

### Transducers and sensors

**Photodetector.** Centronic's OS135 series of devices has a photodiode mounted together with an amplifier in an hermetically sealed TO8 package with a low profile cap. Simplified system design should be possible through elimination of a head amplifier. Four versions: UV (250-400nm); visible (400-900nm); ir (600-1100nm) and eye response are available. Centronic, 0689 42121.



LIMA A6 surface-mounting toggle switches, distributed by Arrow-Hart.

## COMPUTER

### Data communications products

**Processor.** Primarily designed as a serial i/o module, the BVME775 6U VME card can be used as a general-purpose CPU card or stand-alone single-board computer. Its CPU is a 68000 or 68010 running at 12.5MHz and it has eight RS232/RS422 serial channels. It can be configured up to 0.5MB of 150ns dual port static ram accessible to local bus and VMEbus. BVM, 0703 270770.

**Communications controller.** Celdis has extended its range of Zilog microcontrollers with its type 16C30 – delivering four times the transmission rate of current two-channel industry standard SCCs. It operates at a data rate of 10MB/s which Celdis says is the fastest available. Bus bandwidth has been improved to 12.5MB/s. The dev.ce can operate two protocols simultaneously. Celdis, 0734 585171.

**Signal processing codec filter.** Siemens SICOFI-2 for ISDN switching systems can process two channels on one chip. An IOM-2 interface should avoid compatibility problems and programmable filter

coefficients will enable matching of national standards. Power consumption is maximum 5mW for both channels in power-down mode. Siemens, 0932 752323.

### Software

**PCB design.** RUN Electronic Design System for the Apple Macintosh, can deal with surface-mounted devices on a multilayer board, and PCBs up to  $32 \times 32$ in with up to 50 layers can be created with an internal resolution of 0.0005in. Autoroute algorithms included, and up to 24 signal and power layers. Prices from \$1000 to \$9500. Formula GmbH, (W. Germ.) 091 128 6660.

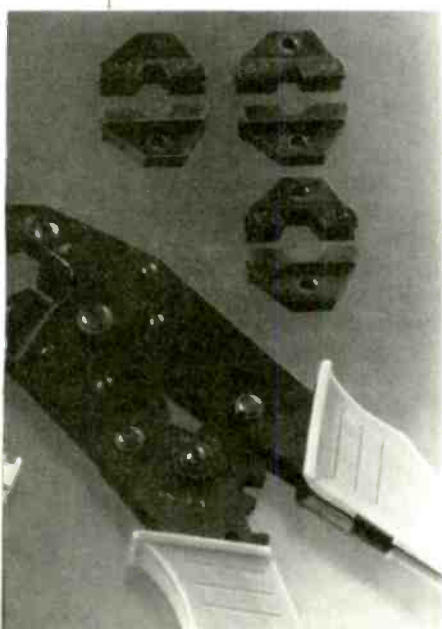
**Image processing.** Real-time display, full image set-up, acquisition and analysis control are the features of MetraByte's MV-RMAC designed for use with PC/XT/ATs and compatibles. Systems must be equipped with MetraBytes's MV1 frame/line grabber board. Menu selection should allow inexperienced users to access all features. Keithley Instruments, 0734 861287.

**PC-based network management.** CMS Nucleus 200 is network software for PC/XT/

AT PS2 and compatibles with Rascal-Milgo says offers the benefits of mini-computer systems, but at lower cost. It will control up to 512 devices. Operator training is minimized through mouse control and windows/menus. Facilities include monitoring, testing and database management. Rascal-Milgo, 0256 763911.

**PCB design.** Cadstar Professional, running on PC AT, PS/23, Compaq 386 or compatibles, will help with design of large, complex, multilayer PCBs encompassing surface-mount and fine-line technologies. The enhanced version of the standard Cadstar package will cope with 5400 connections and over 50,000 segments. It has blind and buried via capabilities over all 16 permitted layers. Rascal-Redac (UK), 0684 294161.

**Back-up utility.** SitBack from Roalan is a memory-resident utility especially useful for users who forgot to back up their files. At defined intervals SitBack will back up created or changed files without disturbing normal use of the PC, and without user intervention. Uses 13k system memory and costs £99. Rcalan International, 0202 861512.



## Relative FSK

Apart from the idea of relativity, which does not enter into the design of either transmitting or receiving circuits, the 'Hypothesis' (F.R. Connor, December 1989 *EW + WW*) appears to be that signal can be separated from noise by transmitting through two channels and eliminating phase noise by taking the sum and difference of the two received signals.

Unfortunately, experience shows that noise is completely random, whether observed as amplitude or phase noise, so that there is no correlation between the phase noise in two different channels: there is then no difference between *subtraction* and *addition* of the noise in two channels. The proof from experience is that noise *power* is proportional to bandwidth: if the noise (e.g. phase noise) were correlated so that waveforms could be added or subtracted, the noise power would increase as the square of the bandwidth of any given channel. The hypothesis is thus contradicted by experience.

D.A. Bell  
Beverley  
North Humberside

In the first article of the series<sup>1</sup> published early in 1989 I stated: "Shannon derived a precise mathematical expression for the capacity *C*, and since its derivation makes no assumptions about the nature of the system (e.g. its linearity or type of modulation or coding etc.) it is a truly fundamental limit..." The concluding sentence of my final article was: "I may also serve to reduce the number of attempts to achieve the impossible".

Sadly, F.R. Connor<sup>2</sup> appears not to heed the latter or to believe the former, since he produces his own expression for *C* which exceeds the Shannon limit. Needless to say, his relative frequency shift keying scheme is based on a

## Electronics and hairdressing

We refer to your editorial in the September 1989 issue of *Electronics & Wireless World* - A nation of hairdressers.

Our impression of recent scientific and engineering graduates is that 30% believe the whole solar system revolves around them!

The other 70% are sensible, hardworking souls who will soon be a credit to their profession.

Glyn Craig  
Microdyne cc  
Edenvale  
Transvaal  
Rep. of South Africa

fundamental fallacy. Shannon will not be beaten! (Although the sub-heading implies a claim only to approach the Shannon limit, the "modified" expression for *C* is inconsistent with this.)

Connor's concept might have some chance of success if the only noise in the system were input, together with the baseband data signal, at the input to the transmitter. However, most operators prefer not deliberately to degrade their signals in this way!

The noise we are normally concerned with is a combination of external interference and receiver noise. The contributions of these in the two channels of Connor's system are *not* correlated. It is also well known and easily demonstrated that the sum and difference of two independent noise waveforms are themselves uncorrelated. So, regrettably, Connor's scheme would merely make the performance worse.

L.C. Walters  
Hampshire

### References

1. "Shannon, Coding and Spread-Spectrum", *Electronics & Wireless World*, January, March, April, May 1989.
2. "Relative Frequency Shift Keying", F.R. Connor, *Electronics World + Wireless World*, December 1989.

## Boring story

I have watched the correspondence over The Theory of Relativity for a seemingly interminable time and, while this may have

connections with electronics, when the entirely mechanical gyroscope appeared in your columns I thought that someone among your learned and erudite readers may care to consider the following.

Some 40 years ago, while carrying out my National Service duties in the Royal Engineers, I came across explosive devices called shaped charges and I was intrigued then, and still am, because these things appear to contravene Newton's third law, which says that every force has an equal and opposite force opposing it.

For those not familiar with shaped charges, the ones we used were called beehive charges and took the form of a cylindrical metal can with a convex conical top, all about 8in diameter and 10in high, with a concave conical bottom, and standing on three legs about 6in long. The can was filled with a high explosive and detonated with a primer in a hole in the top centre of the can. If one of these was stood on a concrete block, not fastened down in any way, and fired, a clean hole about 2in diameter was punched straight down into the concrete some 18in to 2ft deep. Alternatively, if stood on top of a steel girder (I-beam) on the centreline, the hole would be straight through the top flange, the web and the bottom flange.

We were told that these worked because the detonation wave propagated in a conical shape in the direction in which it started, inverting the cone as it went, blew the bottom out of the can, and it was the light copper

'bullet' formed from the bottom of the can which punched the hole. Now I can see that after the explosive has gone, the very light metal structure which is left may possibly have enough mass left to provide a reaction to the cutting blast if it goes off in the opposite direction fast enough, but then consider the method we used to cut railway lines.

We used two slabs of gun-cotton, which I believe to be nitro-cellulose, formed into rigid slabs about 8in - 3in - 1½in and weighing 1 pound each. These are fired from a primer fitted into a hole through the large face, and are entirely naked, having no casing or wrapping of any kind. To cut a railway line, one of these would be taped to each side of the rail, staggered so that the corners were level, with the primer pointing to the rail, and fired simultaneously at both sides. The result would be a clean cut right through the rail, and no debris. Again, we were told that the detonation wave propagated through the slab in the direction of initiation, until it had passed right through the slab, the two opposing waves cutting the rail with a shearing effect. Since there is nothing left after the explosive has gone, I cannot see anything to provide a reaction to the very large force needed to cut the rail. The rail of course, is supported by the similar charge at the other side, which also appears to have nothing to react against.

K.P. Wood  
Wakefield  
West Yorkshire

## Alpha-torque forces

Dr Bell's letter in your October issue has, somewhat belatedly, drawn my attention to Peter Graneau's paper in June. This shows most interesting and remarkable effects in liquids, particularly the mercury fountain which is so well illustrated, but it is not clear how this supports the contention that electromagnetic theory needs to be overturned. Before we abandon a theory which is

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## MONITORS

### COLOUR MONITORS

Decca 16" 80 series budget range colour monitors. Features include PIL tube, housed in a beautiful leak style case and guaranteed 80 column resolution, features which are only normally seen on colour monitors costing 3 times our price! It is absolutely ready to connect to a host of computer or video outputs. Manufacturers fully tested surplus, sold in little or hardly used condition with 90 day full RTB guarantee. Decca 80 COMPO 75 ohm composite video input with integral audio amp & speaker. Ideal for use with video recorder or our Telebox ST, or any other audio visual use.

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Wang green screen 12" chassis monitor with composite video input. Adjustable for tilt. Requires 12 vdc. Brand new and boxed in perfect condition.

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**Motorola M1000-1005** black & white compact chassis measuring only 11.6H x 12W x 22D. Ideal for CCTV or computer applications. Accepts standard composite or Individual H & V syncs. Needs 12vdc at only 0.8A. Some units may have minor screen blemishes. Fully tested with 30 day guarantee and full data.

£29.00(C)

Fully cased as above in attractive moulded desk standing swivel. Dim 12 x 14.5 x 26cm.

£39.00(C)

**JVC 751** ultra compact chassis monitor for 12vdc 0.7A. Dim 11 x 14 x 18cm. Simple DIY data included to convert to composite video input. Full data. BRAND NEW

£65.00(B)

**20" Black & white** monitors by Aztek, Cotron & National. All solid state, fully cased monitors ideal for all types of AV or CCTV applications. Standard composite video inputs with integral audio amp and speaker. Sold in good used condition - fully tested with 90 day guarantee.

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CIRCLE NO. 134 ON REPLY CARD

supported by a vast amount of experimental evidence, we need to be sure that any supposed anomalies lie not in the theory, but in the way in which it is being applied, and obviously this needs care.

The paper starts by referring to conducting metals, evidently to solids such as copper, and defines the forces on current elements as those on the atoms of the conductor, not on the electrons. But this seems to destroy the thesis on which the argument rests. Since the force is electrodynamic, and is caused by the moving electrons, equality of action-reaction demands that the reaction must necessarily be on those electrons, not on the stationary charges.

The essential feature of conduction, in solid copper, is the freedom of the conduction electrons to move in the axial direction, independently of the crystal lattice. In a superconductor the movement is entirely unconstrained. Obviously we have to be very clear what we mean by the axial force on such an element, consisting of two independent components. Since the moving electrons in one are the source of the "magnetic" force on the other, the action-reaction principle predicts that the reaction force acts on those electrons, not on the stationary charges, which (by definition) can make no contribution to the electrodynamic interaction. The problem disappears when considering transverse components of force, since the electrodynamic force on the electrons displaces them sideways, relative to the crystal lattice, causing *electrostatic* forces, which appear as the Hall EMF. These electrostatic forces keep the electrons in equilibrium, and act also on the lattice, thus causing a "ponderomotive" force. But there is no obvious mechanism for such a force transfer from the electrons to the lattice in the axial direction. Thus it is hardly surprising that experiments to observe a reaction on the lattice

have failed, since we would expect to look for it on the electrons, and we can hardly regard the result as a failure of electromagnetic theory, merely a failure to apply it properly.

We must necessarily regard a current element as two groups of charge, not one, and this becomes particularly important in applying energy principles to derive the alpha forces. If we calculate the forces between parallel currents, for example, by arguing that the mechanical work is balanced by the change in stored energy, we get the wrong answer.

The forces tend to push the wires apart, and this increases the inductance, and stored energy, instead of reducing it. The reason, of course, is that there are three sources of energy, not two, because electrical work has to be expended to keep the currents constant. It is essential to include the "electromotive forces" – that is, the axial focus on the conduction electrons – and this

directly illustrates the reaction force which Peter Graneau suggests is missing. It is a very "real" force, and contributes just as much energy (in fact more) to the system as does the mechanical work. But it seems to be ignored in the argument by which the alpha force is deduced, and if we take it into account then there is no anomaly in the forces predicted by conventional theory. Those interested in pursuing the latter further will find the question of forces between current elements discussed in a recent IEE paper (*Proc. IEE*, 136A, May 1989 pp101-113) in which I have argued that it can be simplified by treating electromagnetic energy and momentum as a property of the charges themselves, instead of the fields around them. This has the effect of describing all electromagnetic forces directly in terms of interactions between charges, but can be translated directly into conventional field-theory terms.

The evidence which Peter Graneau gives to support the alpha force relates not to solids, but liquids, and these are most interesting experimental observations. They certainly justify close study and further work, but provide no obvious evidence to support the suggestion that electromagnetic theory fails. The Lorentz force predicts magnetic stirring in liquid metals, as we see by expanding the product  $\nabla(H \cdot B/2)$ ,

$$J \times B = \nabla(H \cdot B/2) + (H \cdot \nabla) B$$

in which the first term is a conservative, or hydrostatic-type pressure proportional to the field energy, but the second is non-conservative, showing that DC can produce a net force, and hence a fluid circulation, around closed curves. This does not appear to explain the mercury "fountain", but the first term will subject the fluid to an upwards force, due to the change in  $H \cdot B/2$  pressure in a manner akin to the projectile forces in an electromagnetic railgun, pointing upwards, so that the vertical electrode corresponds to one of the rails. As I have explained in the IEE paper, these forces provide a direct illustration of electromagnetic momentum, measured by the vector  $A$ .

Going from a solid to a fluid removes the crystal structure and produces results which will, in general, depend on the nature of the fluid. Conduction may, for example, be due to two groups of ions, carrying opposite charge and, possibly, similar mass, moving in opposite directions and subjected to opposite forces. Do the alpha forces act on one or other of these, or on the uncharged liquid? If we apply electromagnetic theory to the forces on the ions we find that, far from no axial force, we have a great deal, since the process of current flow requires a supply voltage, producing a force on the ions in the direction of flow, and this accounts for the whole of the energy being supplied. Since the

### VDUs and X-rays

Visual display units of the type used in computers produce low level X-ray type radiation. The apparent high incidence of birth abnormalities associated with women operating VDU equipment can be explained in terms of the known effects of radiation on health. Similar effects have not been observed in regard to the dangers of television sets because the observer is much further away from the set than is the case with VDU equipment. The intensity of X-ray or other radiation will decrease in inverse proportion to the square of the distance between the observer and the source.

The X-ray levels to which VDU operators have been exposed are up to 0.3 millirems per hour, this level having been measured by the US National Institute for Occupational Safety

and Health. A typical chest X-ray can be taken as equivalent to 30 millirems. One X-ray is thus equivalent to 30/0.3 or 100 hours of working time in front of a VDU screen. The dangers of X-rays to pregnant women are well known and for this reason X-rays are no longer used in the examination of pregnant women. The dangers are more severe in the early stages of pregnancy.

If it is assumed that a VDU operator works for 25 weeks with a VDU equipment emitting only one tenth of the level of 0.3 millirems per hour the equivalent dosage in favourable circumstances is thus

$$0.3 \times 40 \times 25 / (30 \times 10) = 1.0$$

X-rays to chest or abdomen.  
J.A. Corbyn  
Marlborough  
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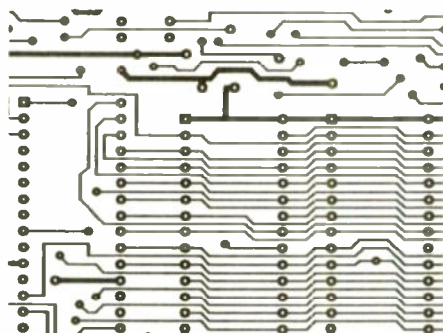
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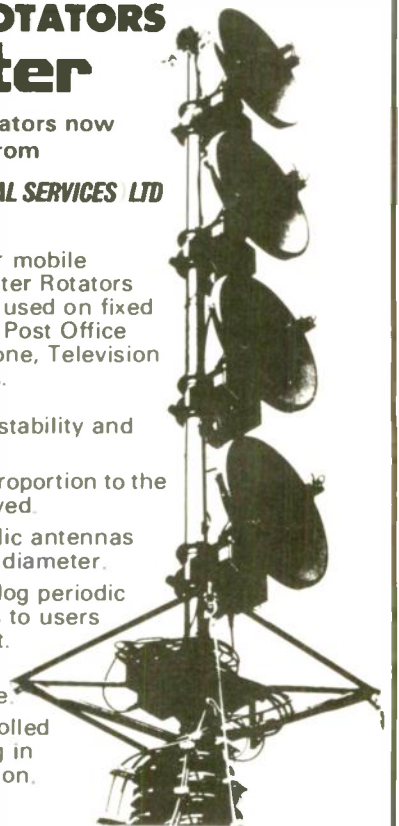
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CIRCLE NO. 138 ON REPLY CARD

ions acquire momentum  $\mu$ , any significant mass  $m$  might be expected to produce a "fountain", and this would then become a beautiful illustration of their momentum, interpreted in the familiar "mechanical" sense. Clearly the details require close investigation, but there is no obvious reason for supposing that the observations are incompatible with electromagnetic theory, or support a theory which treats a current element as a single entity.

C.J. Carpenter (Visiting Fellow)  
Dept of Electrical and Electronic  
Engineering  
University of Bristol

### Low-speed modem

With reference to the mention of the Admiralty Research Establishment's low-speed modem in RF Connections (November, p.1121) your readers may be interested in more detail. This development is only one of several being pursued by the Ministry of Defence research establishments, all of them designed to improve radio data communication.

The low-speed modem already referred to offers highly reliable communication in the presence of noise, interference and fading. Its initial application has been for long range communication in the HF band at low power levels, and therefore reliability has been the priority. In different power and frequency environments, the concept can be adapted to provide higher speed.

Also in the HF band is a development by RSRE, in conjunction with UMIST, of the adaptive chirp modem. In this case, the information is contained within the phase of a chirp signal, the receiver using spectral analysis techniques to reject interference. This has been shown to provide significant improvement over FSK at 75 b/s, and development of a 600 b/s version is in hand.

A further modem development has been by RAE,

primarily for VHF/UHF communication. A modification of frequency exchange keying using coherent signals is used, providing 16 Kb/s with greatly reduced sidebands, thus minimizing spectrum pollution. The technique results in a more constant envelope characteristic, hence more effective use of power, an important benefit in a power-limited regulated environment.

Such is the algorithm that reconstructs the original message that successful transmission with an acceptable error rate has been shown to be possible with signal-to-interference ratios down to +30dB. Transmission power requirements are therefore minimal, and the transmissions can be very secure as they may not be easily detectable. Further, multipath propagation improves the transmission and reduces the error rate.

The modem can also be operated in re-send mode, whereby a message that has been received with an unacceptably high error rate is re-sent, and the second transmission automatically compared with the previously stored first transmission. It is highly unlikely that the same errors will occur in the same place twice, so, for example, two transmissions each of 10% error rate will result in an overall error rate of significantly less than 1%. This is used in the HF band, where it provides reliable long distance communication at very low transmission power. However, the modem could be applied in other bands wherever the need for reliable communication at low power is required.

If you are interested in the possibility of licensing this technology, please contact: Simon R. Atkinson  
Defence Technology Enterprises Ltd  
Norfolk House  
433a Silbury Boulevard  
Central Milton Keynes  
MK9 2HA  
The equipment and techniques described above have been patented.

### Licence to make money

I was pleased to read T. Jeffrey Burton's letter in December Letters and generally endorse his comments. However, I am concerned that, whilst he has precisely identified the cause of the 'undervalued engineer', he appears to presume that a legislative body might be the solution.

I believe this is a wholly unwise goal to campaign for. Such organizations are likely to be so damaging to the innovative nature of electronics, indeed science in general, that we may find the entire UK electronics industry reduced to the lumbering uninspired megaliths of GEC, Plessey and the like.

The result of such a body carrying weight in law could easily prevent a company from either licensing or selling its unique and innovative product simply because their engineers

were not formally qualified.

Invention is the essence of successful technology; we must not stifle it. No, we do need legislation to protect and reward engineers and I believe this must take a form of protection of the original innovator. It must be quite different from the current patent laws, which are generally beyond the finances of individuals. A future law should not allow the entire rights of ownership of design to be wholly passed on to the employing body. In operation, an employer could not legally employ an engineer to design and be done with; instead he would be forced to make a commitment to reward the originator in return for the successful business created.

Tim Craig  
The Graphics Laboratory  
Bristol

### Risc Mips

Rupert Baines article Who's who in risc (November 1989 EW + WW) credits the Intel 860 co-processor with "150 Mips performance, more than seven times as fast as its nearest competitor". Absolute nonsense! For a company with no history of developing advanced architectures (best not to mention the iAPX 432!), the 860 is a very commendable product. However, its performance running real programs is virtually the same as the IDT/MIPS 79R3000, which Baines correctly acknowledges as the highest performance risc architecture in production today.

Such contrary positions arise because people have differing interpretations of a Mip, ranging from millions of instructions per second at one extreme (or native Mips), to machine relative Mips such as VAX-Mips. To make an audio analogy, sustained VAX-Mips could be said to be continuous power per channel of an amplifier in watts. By

contrast, peak native Mips equate to those words beloved by advertisers, total peak music power!

Promulgation in the media of performance numbers such as peak native Mips are one of the primary reasons for confusion in the risc marketplace. Potential users are unable to relate such units of performance to the system performance they might realise in their particular design.

A telling observation one could make about the various risc architectures is that, despite having the R2000/3000 architecture as a "role model" for several years, the best other designs have achieved is to equal the R3000 performance, as the 860 does. Most don't come close. The 860 achieves its performance by the brute-force technique of massive parallelism and very wide internal busses (around 1M transistors). The R3000, by contrast, uses elegant architecture (115 000 transistors) and sophisticated optimizing

compilers. Those who think the 860 is as truly wonderful as Baines claims should ask Intel why they are redesigning it.

Most semiconductor market analysts are predicting that the R3000 and the Sun Sparc processor will share equally about 70% of the risc market by the mid 1990s. All other risc suppliers will have to fight over the remaining 30%. It is worth noting that 35% of market prediction for Sparc results almost entirely from vertical integration within Sun Microsystems. By contrast R3000 is used by DEC, CDC, Sony, Bull, Siemens, Nixdorf, Prime, Ardent and many other blue-chip corporations. Steve Bennett  
Manager European Applications  
IDT Europe Ltd.  
Leatherhead

### RIP cold fusion?

In the November letters Dr Aspden states that he can accept cold fusion without the emission of neutrons because his theoretical research assures him – "that there are no neutrons in the deuteron".

Over the years very extensive studies have been made of reactions in which a range of nuclei bombarded with protons appear to absorb them and subsequently to emit deuterons, or alternatively may undergo a "direct reaction" in which the deuteron is simply "stripped" of its neutron by the nucleus. In these studies the energies of the emerging particles and their angular distributions relative to the bombarding particles were accurately measured. The angular distributions observed when the target nuclei were isotopes of the "proton magic" elements calcium, tin, and lead are virtually impossible to reconcile with two-stage reactions, but are very well accounted for by systematic calculations in which the processes are regarded as direct pick-up and stripping reactions, as would be expected from the accepted view of a deuteron as a neutron and a proton rather loosely (in terms of nuclear

binding energies) bound together.

Until Dr Aspden has demonstrated that his unconventional theory of the composition of the deuteron can be reconciled with these experiments he cannot reasonably advance it as a justification for believing in fusion without the emission of neutrons.

C. F. Coleman  
Grove  
Oxfordshire

### Light current

Joseph McClean's letter in the September issue prompts me to write regarding a possibly related phenomenon which I have observed in the RA53 thermistor, as used for amplitude control in the classic Wien-bridge oscillator: when a bench lamp was switched on the output amplitude decreased.

I have tried scraping the paint off both ZF and BYZ88 series zeners (memories of doing same to an OC44 to obtain a photo-transistor) but have been unable to observe the effect which Mr McClean describes.

D. M. Bridgen  
Reading  
Berkshire

### Wien oscillator amplitude

A ponderomotive force drives me to reply to Peter Vaughan (Letters, November). Where Lorentz went wrong was in failing to understand anything whatsoever about silicon op-amps, and Relativity fails miserably in explaining the problem described.

Mr Vaughan is clearly a practical man with a practical problem. He is having trouble with questions of exponential growth and exponential decay. He is right in saying that, if an oscillator doubles its amplitude every second, it will grow by about a thousandfold in ten seconds; two to the power ten is 1024. If the switch were open for 24 hours, the signal would decay at this rate, falling by two to the power 86400 or ten to the power

26009.

A signal of  $10^{-26009}$  is absurdly small. The terms atto and femto exist for small units and the googol and googolplex for large ones. However, no term exists for anything like ten to the power minus tens of thousands because such units are never used in the real world.

There is a very simple reason why we do not bother – noise. I remember my first experiments with the Germanium Amplifier No 1 (GA1) from General Electric (US). This had a gain of zilch and a noise figure of plenty. Even with today's devices one would use a rule-of-thumb by saying that the noise voltage is about 100dB down. Very approximately, you would have 100 picovolts of noise in a 1 volt signal, no matter what circuit configuration you tried. It is thermal noise in resistors, quantum noise etc. Bad design would give you much more still.

So, by the time you had opened the switch for about four seconds, the signal would be way below the noise. Leaving the switch open would allow any theoretical signal to fade away, but the noise, say due to  $R_1$ , would still be there. So you waste a day waiting (literally) for nothing.

When the switch is closed, the exponential of the signal would start from the noise level. All oscillator theory – even that of the humble multivibrator – says "assume a small voltage change due to ambient noise". This voltage step is filtered through the frequency-selective feedback path and grows with the loop-gain. Most simple oscillators are then limited by clipping.

I do not know of any experiments that were performed starting up an oscillator repeatedly from cold, and testing the time to reach 1V RMS. Because the oscillation is said to begin with noise, one would expect a randomness of timing. However, I do remember a report in *Wireless World* (was it T.D. Towers?) when the silicon field-effect transistor came out, claiming

that with one Wien-bridge design one had to wait for several seconds before the oscillation condescended to start. Low noise, you see, and low loop-gain. I assumed then that the wait was a random one.

Oh, the joys of nostalgia. What luck we've still got John Linsley Hood, but in such a pensive mood, bringing back old memories. I think we lost our Scroggie. Where is Dr Dinsdale? I was tinkering with some Japanese audio gear; the instructions were in Katakana, Harigami, Kanji and Macaroni. In the middle of all this was some latin script! It read "Baxandall"! I think they were discussing the tone-control provisions. Where is Peter now? Dear Editor, please give us back our adverts. Please give us back our constructional articles and design studies. Please give us back our favourite creative engineers. Please give us back our name. *Wireless World* was the British electronics industry; a meeting-place of designers and vendors. An institution. Without it, Britain is post-industrial.

Charles Wehner  
Blaenau-Ffestiniog  
Gwyneth  
North Wales

### Integrated engineering degree

In your November 1989 issue (p.1054) you report the go-ahead for six pilot schemes for a new Integrated Engineering Degree Programme in a joint initiative by the Engineering Council and the DTI. Five contracting universities and polytechnics are listed. The University of Wales College of Cardiff is omitted. To select five from, say, twenty is to be discerning. However, a selection of five from six is discriminating!

Would you be kind enough to let your readers know that we too are to mount this excellent course.

Dr R.D. Jones  
Deputy Head, School of  
Engineering  
University of Wales  
Cardiff

# PIONEERS

**H**e was perhaps the 20th century's greatest mathematician. And judging from the stories that are told about him, he must have been quite a character; he certainly had one of the greatest minds of our age. Problems that took others ages to solve, he seemed to crack in a flash. He had a most extraordinary ability for fast mental calculations and for recalling from memory an immense range of facts. So pre-eminent was he, and not just in one or two fields of science, that some leading scientists even asked if he might represent a new stage in human mental development.

John von Neumann has given his name to the modern computer; to many engineers they are von Neumann machines. The reason for this accolade is that it was he who originated the pivotal concept of storing the program in the computer's memory. That may not sound so impressive now because we have grown accustomed to it, but in so doing he laid down the blueprint for the modern computer.

But it is not only the computer that bears his name. A professorship and a centre for scientific computing at Princeton University have been named after him, and on the far side of the moon there is a von Neumann crater. At one time a street corner was nick-named in his honour because he crashed his car there so often. Apparently he was regularly stopped for speeding. "The way he drove," said a friend, "a car couldn't possibly last more than a year."

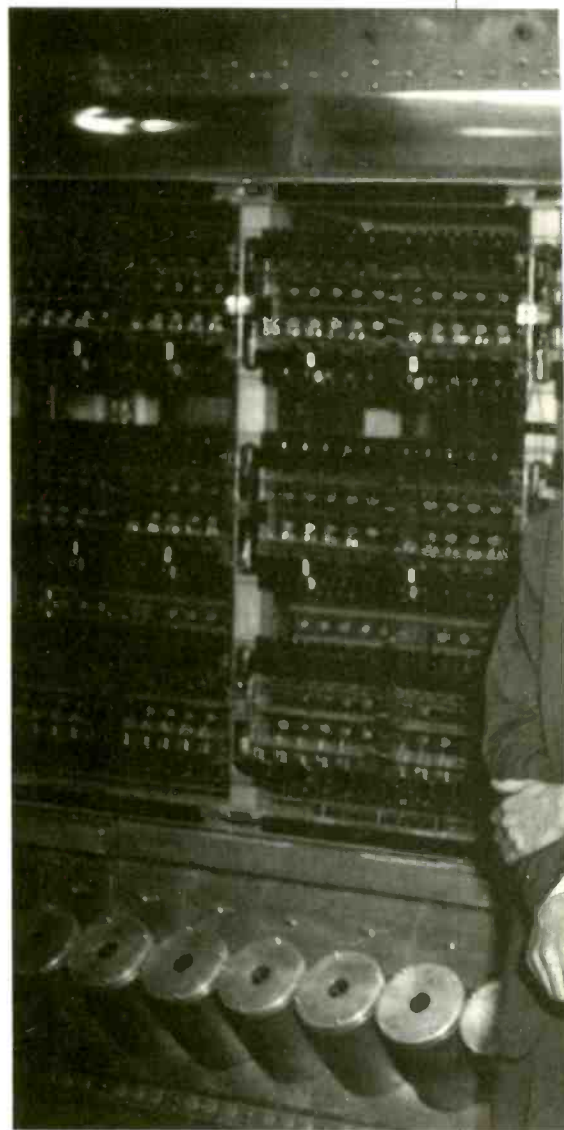
He was eminent in three main fields (though driving was not one of them); first, in mathematics, both pure and applied. It has been suggested that he might be the last of what was once a numerous and flourishing group, those mathematicians who were equally at home in both pure and applied mathematics and who maintained a steady contribution to both. In a profession where agile minds and quickness of thought are common, his abilities were proverbial. He even invented a new

John von Neumann  
(1903-1957)  
Computers, Joan of  
Arc, and Byzantine  
Emperors

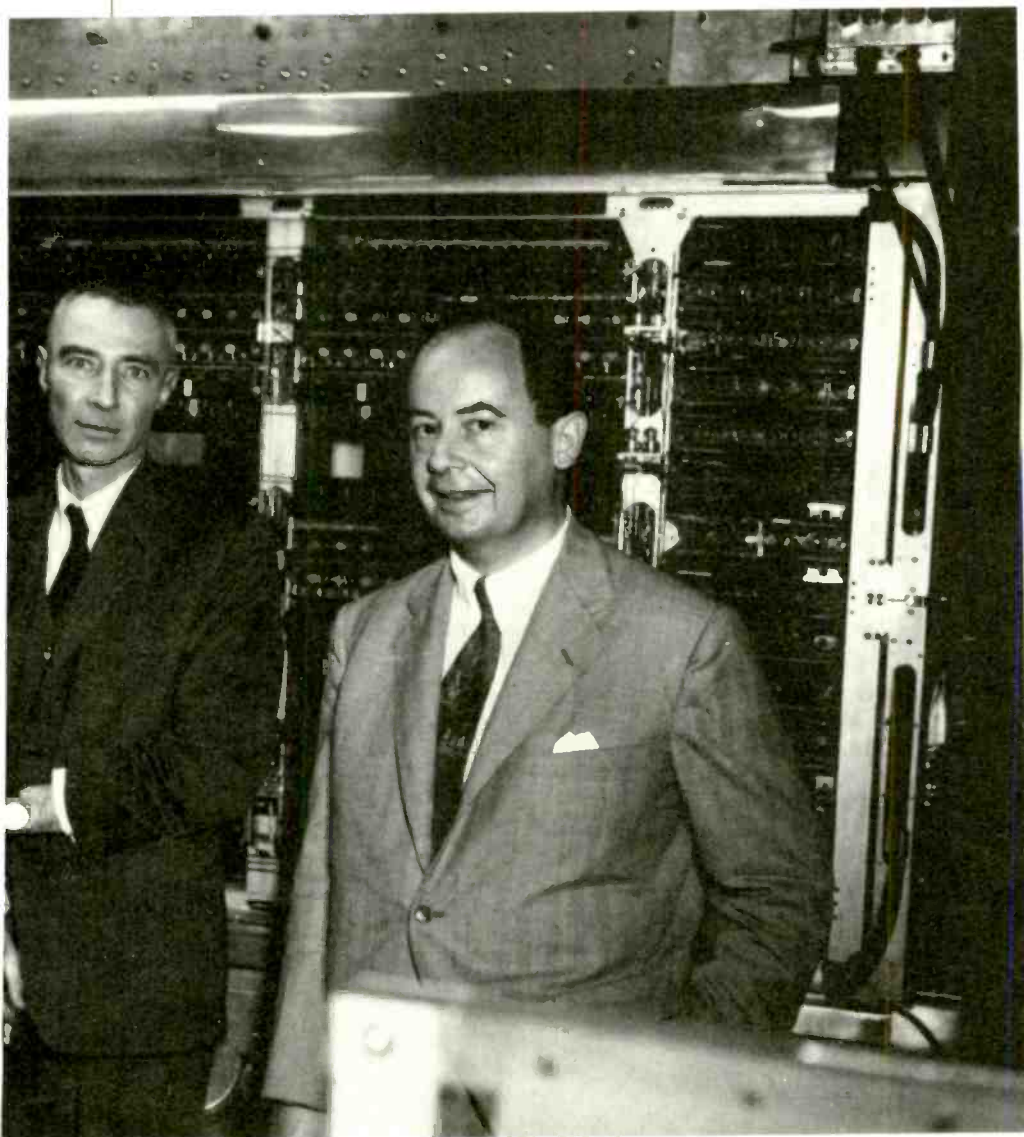
*John von Neumann (right) and Robert Oppenheimer in front of EDVAC, for which von Neumann produced the logic design. Picture courtesy Institute for Advanced Study, Princeton.*

branch of mathematics; game theory. Despite its title, its uses range beyond games to social and economic behaviour and strategy in war.

His second major field of interest was quantum theory, to which he contributed at the early age of 23. He worked on the atom bomb project and one of his last posts was a member of the US Atomic Energy Commission. In 1954 he forecast a long wait before atomic power would be used economically. However, it is in the third field that he is best known to electronics engineers: electronic computers. He was once described by the *New York Times* as the world leader in the development of high-speed computers.



For many years von Neumann played important roles in the scientific establishment of America, but he did not restrict his mind to scientific problems. Oskar Morgenstern, with whom he published the seminal book on the theory of games, has said that the flexibility of his mind made him a most entertaining companion as he used both his scientific knowledge and his wide reading of other subjects to make jokes and puns. His recreational reading and knowledge ranged from the procedural details of the trial of Joan of Arc to the genealogy of Byzantine emperors and details of ancient battles. He enjoyed poetry and spoke many languages, speaking faster (so it was said) in seven



languages than most people do in their own. Morgenstern's memorial to von Neumann concluded: "To state that we witnessed a combination of purest genius with a seemingly unbounded vitality and energy is a feeble way to give expression of the singularity of this man."<sup>1</sup>

### The von Neumann machine

In 1944 John von Neumann became involved with the group at the Moore School of Electrical Engineering at the University of Pennsylvania who were designing and building ENIAC (Electronic Numerical Integrator and Calculator), the first general-purpose electronic computer. A number of strings of

development were coming together about that time: automatic control techniques learned for gun directors, punched-card accounting machines and the new techniques for calculation.

Programs for the early computers were usually stored on punched paper tape, plug boards or, as with ENIAC, within the wiring of the machine. When the ENIAC team turned to the design of a second and more powerful machine, they incorporated the concept of storing the program within the electronic memory of the computer. Logical decisions could then be made by the machine between choices of program sequences. This stored-program concept was the essential new element of the von

Neumann machine. Its origin is credited to von Neumann and to others in the ENIAC group.

The new machine, to be known as EDVAC (Electronic Discrete Variable Automatic Computer), was the prototype for the future; John von Neumann produced the complete logical design. He described it in a paper, "First Draft of a Report on the EDVAC" dated 30th June, 1945. It was the first document to discuss the stored-program machine, the general-purpose computer we know today.

The EDVAC logical design received wide publicity and the concepts were picked up by others. In the summer of 1946, the Moore School hosted a course on computer design which served as a catalyst for development in both the USA and Britain. The Cambridge University EDSAC became the first working machine to incorporate the ideas.

After the war von Neumann was joined at the Institute of Advanced Study (IAS) at Princeton University by colleagues from the computer projects. They set about designing a third computer, which became known as the IAS computer. The IAS had a policy of not doing experimental work, but in Autumn 1945 an exception was made to allow von Neumann and his colleagues to develop their machine. "It is to be expected," he wrote, "that the future evolution of high-speed computing will be decisively influenced by experiences gained." Their subsequent reports have been described as "the most important tutorial documents in the early development of electronic computers". Amongst all this early work was a notation from which was developed the flow-diagram techniques commonly used in program design.

John von Neumann recognised very early that computers would find applications in business and one of his first programs was for "sorting". Another application he foresaw was in calculating models of the atmosphere to aid weather forecasting. As early as 1946 he announced his intention of producing a computer-aided weather forecast. In 1950 he and his group were ready; they used ENIAC to calculate a 24-hour weather forecast in 24 hours. Other applications for computers were also investigated: his theory of games (1937) helped to model a duel between a destroyer and a submarine.

Later, his ideas were to extend to

cybernetics, the theory of automata and the possibility of achieving self-reproducing automatic machines. In pursuing the latter he at one stage bought the biggest toy construction set he could lay his hands on before realising that he could represent the machine in two dimensions. Shortly afterwards a colleague's son received a magnificent gift.

### A waste of time

John von Neumann was born in Budapest in 1903 on the 28th December. He was the eldest of the three sons of Max and Margaret von Neumann, his father being a well-to-do Jewish banker. He was privately educated until 1914 when he started secondary school. There his teachers decided that teaching him conventional school mathematics was a waste of time and so he was educated in mathematics under the guidance of university professors. At the age of 19 he was already recognised as a mathematician and had published his first paper.

His university education was pure Central European: University of Berlin (1921-23), Institute of Polytechnics at Zurich (1923-25) and finally the University of Budapest in 1926 where he received his Ph.D. He then worked on quantum mechanics at Göttingen before beginning to lecture, first at Berlin and then at Hamburg. In 1930 he realised a long-held dream by leaving for the USA. "It was the attraction of a much larger country with a much more stable government and wider scientific possibilities that brought me here," he has been reported as saying. But first he got married, to 18-year old Mariette Kovesi. Their only child, Marina, was born in 1935.

From 1930 to 1933, he was a visiting professor of mathematical physics at Princeton University before being invited to join the newly-formed Institute for Advanced Study (at Princeton)

*"I have sometimes wondered whether a brain like von Neumann's does not indicate a species superior to that of man."  
Hans Bethe*

where he was the youngest permanent member, so young that he was often mistaken for a student. There he rubbed shoulders with other scientific geniuses of the century, Albert Einstein included.

Apparently, von Neumann was not the ideal lecturer. His lectures, though brilliant, were difficult to follow, but for those who could keep up with him he was an inspiration. His habit of filling the blackboard with equations, rubbing them off and filling the board again as he worked through a problem led to comments like, "Proof by erasure".

Tales about him are plentiful, from his encyclopaedic knowledge of the family trees of European royalty to his love of a noisy environment for his work. He dressed smartly and one fellow scientist once remarked, "Johnny, why don't you smear some chalk dust on your coat so you look like the rest of us?" He loved food, "especially rich sauces and desserts", regarded exercise as "nonsense" and described himself as "anti-musical". But he loved a party, gave stiff drinks and, despite his amazing memory, found it difficult to remember people's names.

He was proud of his brain power and once described his job matter-of-factly – and correctly – as involving, "high mathematics and lots of scientific terms that very few could understand."

In 1937 he became an American citizen, was elected to the US Academy of Science, and his marriage ended in divorce. The following year, on a trip to Budapest, he met and married his second wife, Klara Dan. This union lasted until his death in 1957.

As the Second World War approached, military work became increasingly important to the university. From ballistics and submarine warfare, von Neumann turned to the atomic bomb project at Los Alamos, to which he made major contributions. After the war his work on high-speed computers hastened the work on the American H-bomb. He was a "hawk" as regards "preventive war" and in the early 1950s he advocated shooting first.

By this time his main work was directed at computers, though his mind was in demand to help solve many other problems. In October 1954 President Eisenhower appointed him a member of the US Atomic Energy Commission (AEC). Only six months later he was examined for a pain in his shoulder. It was secondary cancer. When the primary cancer was traced the doctors informed him that he did not have long left.

*"To his many friends, his students, his colleagues, Dr. von Neumann was the highest and liveliest intelligence they were ever to encounter."*

*Robert Oppenheimer*

He continued with his official work, both for the AEC and as chairman of the Air Force ballistic missile committee, even to the extent of delaying his remaining personal scientific work on the workings of the human brain. This, he hoped, would help in developing even better computers and automata.

By January 1956, he was confined to a wheelchair. Honours flowed in, including the US Medal of Freedom, and so too did the visitors, anxious to make use of his prodigious talents whilst they were still available. In April 1956 he entered hospital on a permanent basis. He turned again to the Roman Catholic religion he had once practised, but needed an "intellectually compatible" priest for his discussions.

As the cancer spread, his family gathered to support him, including his two brothers and his 76 year-old mother who, though he did not know it, was also dying of cancer. His body, like his brain, proved better than expected and gave him six or seven months more than his doctors had expected. His death on the 8th February, 1957, at the age of 53, robbed the world of many years further benefit from his superbrain.

### Reference

I. O. Morgenstern, *Princeton Alumni Weekly*, 12 May, 1961.

*The author acknowledges the help provided by the Princeton University Archives.*

*Tony Atherton's book on the history of electrical and electronic engineering, "From Compass to Computer" was published in 1984 by Macmillan.*

# Electronic ignition

**T**he traditional winter morning sight of motorists battling to breathe life into frozen engines is becoming less common as modern ignition systems are made to brave harsher and harsher climates. There is though still room for improvement before the "I know a man who can" man can look forward to a lie-in.

Electronic ignition systems started life as an after sales add-on, the latest gimmick to beat the old mechanically switched system. They were invariably capacitor discharge systems and for good reasons: the standard ignition coil was still there.

Inductive discharge systems were not possible without a change of coil due to a lack of high voltage power switching transistors. It was the HV power bipolar transistor that changed things.

Unfortunately by then the standard coil had come to the end of its life in favour of low inductance coils with ballast resistors to improve cold starting. Thus the bipolar transistor was called to switch about 6A. To do so reliably, safe operating clamps were needed raising costs and dissipation.

Power mosfets on the other hand are majority carrier devices and are not subject to second breakdown, so they do not need safe operating area clamping. The suitability of power mosfets

has sometimes been overlooked because of concern over the mosfets resistance due to the high voltage rating required. But all the necessary specifications can be met including crank voltage performance with a higher efficiency than typically found in systems using bipolar transistors.

Today's ignition modules have not changed dramatically over the years but higher efficiencies can be achieved using a lower current high inductance coil. Ignition requirements for modern engines fall into four categories — aiming voltage at the spark plug, available energy from the coil, spark duration, and crank voltage.

The aiming voltage requirement is the open circuit voltage at the high tension terminal of the coil before the inter-electrode gap of the spark plug breaks down. This should not be confused with the arc voltage across the spark plug's gap after breakdown. The aiming voltage is normally specified as 16kV at a minimum battery voltage of 13.2V. It should be as high as possible without endangering coil winding insulation so that it can fire fouled plugs.

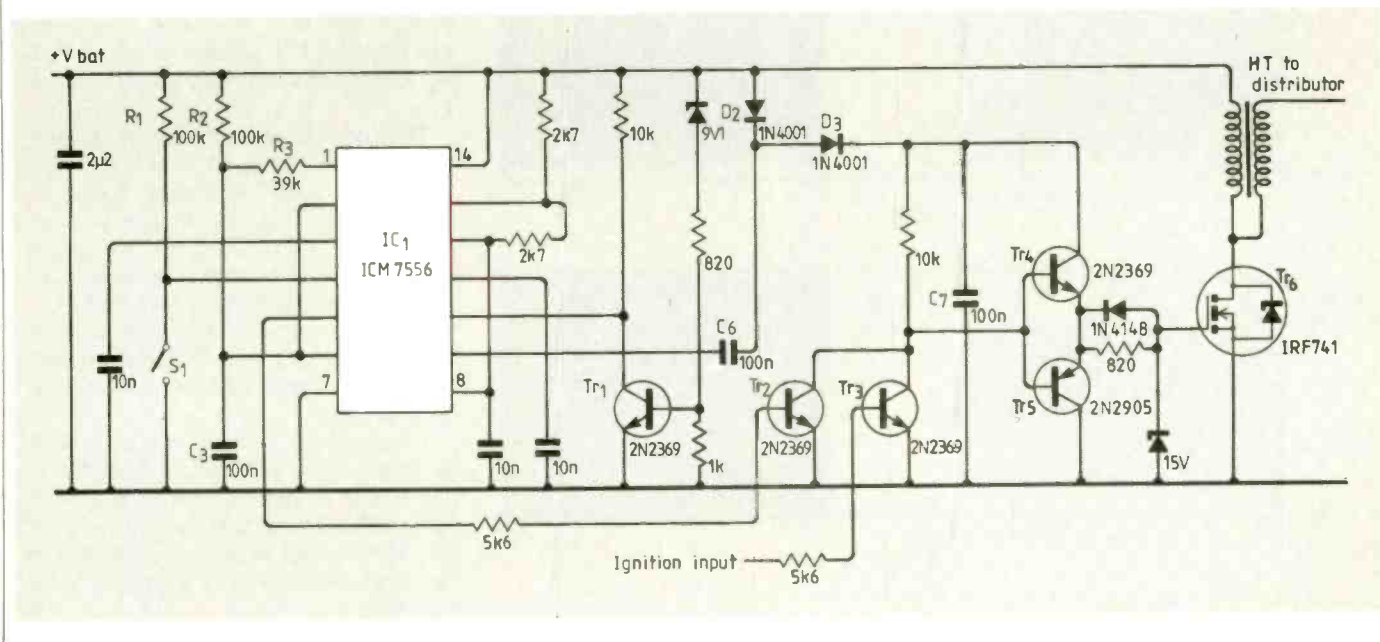
**Fig.1. IC1 acts as a charge pump bias generator to provide 10V enhancement voltage for Tr6 during starting when battery voltage may fall below 6V.**

Minimum available energy from the coil can be as little as 2mJ, though engine specifications frequently quote 6mJ for a crank voltage of 6V. Extrapolating for a crank voltage of 4.5V gives a minimum energy of 4mJ. Too high an energy level will accelerate spark plug electrode erosion.

Many variables determine the requirements for spark duration including the number of cylinders, maximum revolution rate of the engine, fuel and air mixture in the combustion chamber, and static ignition timing when the engine is idle.

Consider an eight cylinder engine running at 6000rev/min. The maximum time interval between the start of one spark and the next is about 2.5ms. Crankshaft angular velocity is 360° in 10ms, or 1° in 27.8µs. Centrifugal advance can be up to 21° btdc (before top dead centre). Frequently quoted spark durations for capacitor discharge systems of 400µs are normally considered adequate.

If the dwell time is 1.8ms maximum then a spark duration of 700µs should be adequate to avoid detonation due to premature extinguishing of the flame front. On the other hand, if the same engine is idle at 800rev/min, the maximum time between the start of one spark and the next is about 18.75ms. Crank shaft angular velocity is 360° in



# APPLICATIONS

75ms or 1° in 208μs. The spark advance at static idle may be 6° btdc.

Here the 400μs spark duration seriously increases the chance of the flame front being prematurely extinguished when the spark stops. This is more likely in modern fuel efficient lean-burn engines.

The volt-second product balance for inductive discharge systems should provide a spark at idle that is long enough to prevent detonation.

Crank voltage can be defined as the available battery voltage while the starter motor is operating. Various specifications for 12V cars place this at 6V and in some particularly bad cases as low as 4.5V.

A bipolar Darlington transistor and a 4mH coil limited to 6A will provide an aiming voltage of 12kV. An 8mH coil limited to 3.5A with a mosfet can provide an aiming voltage of 13kV. Therefore both systems perform equally well with the mosfet system consuming less power and thus being more efficient.

Furthermore, a bipolar Darlington transistor with an 8mH coil would only generate an aiming voltage of 9kV at a crank voltage of 4.5V. This may not be enough to fire the plugs. The 4mJ coil and Darlington would be adequate for the 4.5V crank voltage but power consumption would increase.

To design a mosfet ignition system, the first priority is to pick a coil with as low a primary current as possible. Primary inductance should be a nomi-

nal 8mH, and primary resistance should not be less than 2.5Ω and not more than 3.75Ω. The turns ratio of the coil should be a nominal 55:1.

The recommended mosfet for the power switch is the IRF741 which will give a maximum clamped aiming voltage of 19kV for a minimum drain-to-source breakdown voltage (BV<sub>DSS</sub>) and 21kV for a maximum BV<sub>DSS</sub>. These aiming voltages will not cause internal breakdown in the coil. The maximum BV<sub>DSS</sub> assumed here is the minimum BV<sub>DSS</sub> of the prime voltage version of the IRF741 and 740.

This combination will give an aiming voltage during cranking at 4.5V of 10kV minimum, and a spark energy of 4.7mJ. The specified minimum is typically 4mJ. Spark duration is 150μs minimum. For an eight cylinder engine, the maximum power consumption is 17W at 6000rev/min and 25W at 800rev/min. These correspond to 32 and 42W, respectively, for a 4mJ coil and Darlington bipolar transistor.

The circuit diagram (Fig.1) shows a practical ignition module with built-in test oscillator composed of R1, R2, R3, C3 and half of IC1. This provides a 50Hz 50% duty cycle pulse to the base of Tr2 with S1 open. With S1 closed, normal ignition triggering is via the ignition input, with input high when Tr6 is off.

Tr1, D2, D3, C6, C7 and the second half of IC1 comprise a gated charge pump for maintaining adequate gate voltage for Tr6 for battery voltages less

than 10V during cranking. Tr6 avalanches repetitively and absorbs the energy stored in the leakage inductance of the coil.

Fig. 2 shows the waveforms of HT voltage (upper trace) and drain source voltage (lower trace) across Tr6. The battery voltage is 4.5V and the HT terminal is not terminated. It appears that the spark duration comes to about 150μs but, as can be seen from the waveform in Fig. 3, it is somewhat longer in practice.

In Fig. 3 the time base has been changed to 200μs/div and the lower trace sensitivity to 200V/div. The upper trace sensitivity stays the same. The waveforms show the gap breaking down at about 9kV with the arc sustaining voltage about 2kV. From the lower trace it is clear that the spark duration is about 200μs for a maintained battery voltage of 4.5V.

Fig. 4 shows the waveform with the bridgeable air gap set to 12mm and the battery voltage set to 14V. This would be the minimum voltage during charging that would be seen as typical in a car. The HT waveform is the upper trace and V<sub>DS</sub> of Tr6 is the lower waveform.

The gap breaks down at about 16kV while the arc is maintained for about 1ms. The 500V drain source spike is caused by the leakage inductance of the coil and plays no part in the spark generation. This can be seen in Fig. 5 where the time base speed has been increased to 1μs/div.

In Fig. 5 the HT voltage has only reached about 2kV by the time the leakage reaction spark starts to diminish. The magnitude of the leakage spike amply displays avalanche in the mosfet and this avalanche capability will stop the HT voltage from exceeding a nominal 22kV with an IRF741 for Tr6.

The waveforms in all the photographs were obtained at a frequency compatible with an engine speed of 6000rev/min for an eight-cylinder engine. At idle the increased dwell angle would increase the magnitude of the HT aiming voltages in Figs 2 and 3.

Maximum power consumption at 800 and 6000rev/min was 21.5 and 16.8W, respectively, and is in line with design specifications.

The ignition module in the circuit diagram gives a performance similar to that of any of the better systems available without any sacrifice in cost. It provides savings in power consumption and heat generation, a measure of its reliability. ■

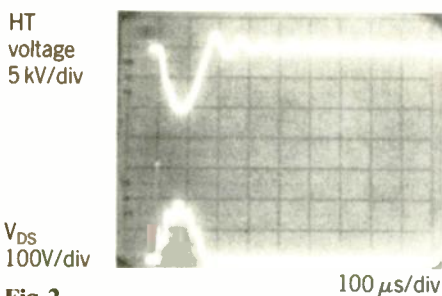


Fig.2

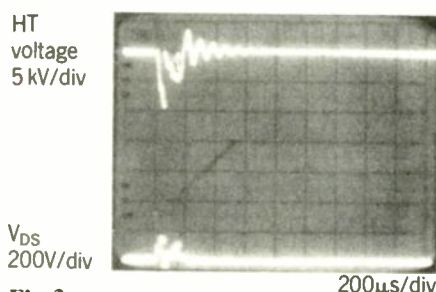


Fig.3

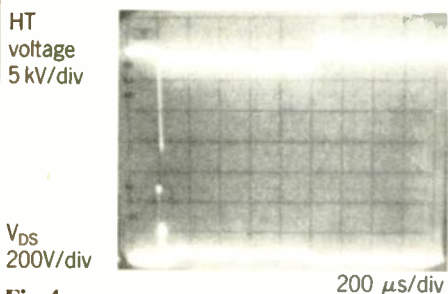


Fig.4

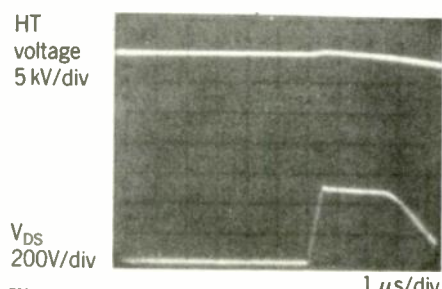
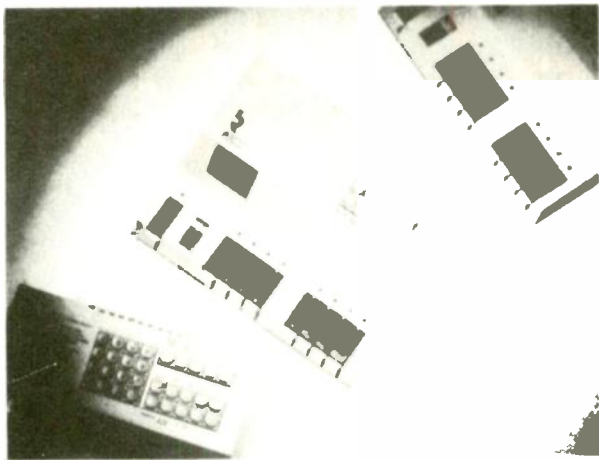


Fig.5

Waveforms H/T voltage copper trace and drain



1.0.0.0



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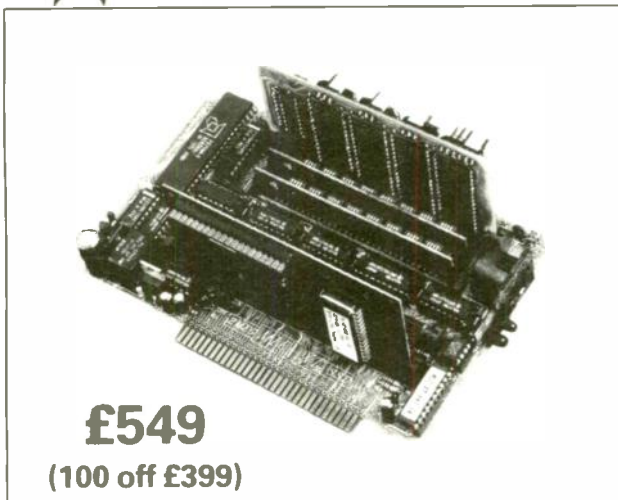


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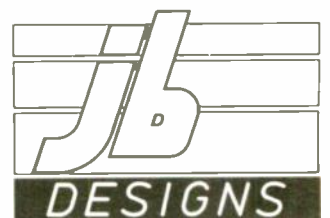
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# PC DRAWING

**D**rawings used in electronics include block diagrams, circuit diagrams, associated mechanical parts, and presentation material. Unfortunately, no-low cost drawing package is suited to all these uses. Mechanical drawing is the most exciting; a package which is good at this often has a useful capability for the others and can come to be the preferred software for many applications.

By "drawing", I mean to imply accuracy, rather than shapes with no particular dimensions. Desirable features include an ability to add extras to a drawing without running out of space and a plot size which can be defined at plot time. In this respect, an on-screen measuring tool which ties in with the final plot size is almost indispensable.

Several packages support a good range of output devices, including dot-matrix printers, laser printers, and plotters.

The industry-standard drawing package has traditionally been Autocad from Autodesk, which costs about £2000 and so is not the sort of package which everyone in electronics is going to rush out and buy. There are several cheaper drawing packages, starting at about £75, though with less capability; some are capable of better work than the early versions of Autocad.

## Low-cost software

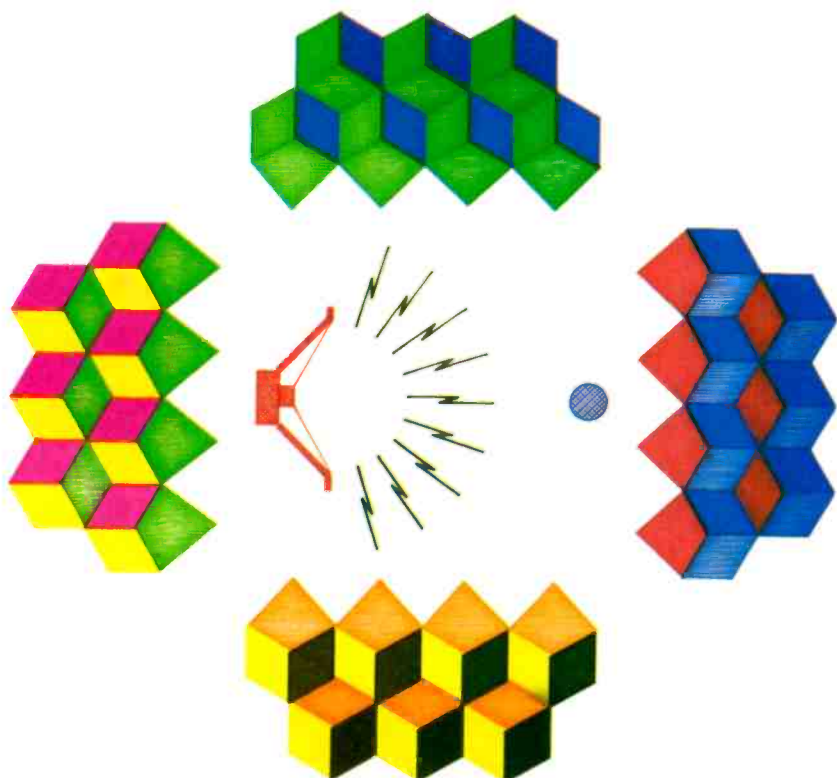
Packages capable of making drawings, in approximate ascending order of cost, include Autosketch, Easycad2, Genericad, Turbocad, Gemdraw, Freelance and Superimage. I used Superimage for about a year, Autosketch for several months, Easycad2 for the last six months and the others for a brief period for comparison purposes.

Acceptability depends not only on the drawing capability, which is obviously important in itself, but also on the ease with which drawings can be edited, for example in selecting bits of a drawing in order to modify them, particularly where these are small and buried

Ken Holford reviews Polaron's Easycad2 PC drawing package, which is inexpensive but by no means lacking in effectiveness

amongst other lines. Having achieved the selection, the assistance given in seeing what will happen when it is modified varies from very little to showing a movable phantom image, while retaining the option to abort.

Some place a box round the selected part and allow the contents to be rotated, stretched or moved, depending on which part of the box is selected, usually very quickly. Others indicate what has been selected by a change in colour or brilliance and several more prompt the user to mark a reference



An example of the possibilities with Easycad2. Note the rotating "sound waves" around the loudspeaker

point on the selection, finally moving or copying the selection to the new cursor position when the mouse is clicked, using the reference point for placement.

The use of a box, as with Superimage, has the advantage of speed in showing size changes, which is useful for moving and placing text, but less so for the accurate joining of lines. There is also no on-screen measuring tool and so plot size is not well defined; the drawing is limited to a page size and often that extra bit of circuit can't quite be fitted in. There was no support file of pre-drawn electrical symbols. Finally, the installation procedure conflicts with other packages. Recently, a new version has appeared (1.5) but I have little experience of this except that 'on-screen' measuring is still not provided; it still uses a page and no plot scaling could be found.

The main claim for Freelance is the support for presentation material, such as pie charts; its engineering-drawing performance is not very impressive.

Gemdraw uses an on-screen ruler along the edge of the page, and the user draws on the page. The package offers circuit-symbol support and runs under the Gem front-end environment, which not everyone likes. Its drawing capability is nothing to shout about, but the icons give a friendly environment for first-time PC users. The need to move a window around to see a part of the drawing was found particularly annoying and Easycad users would be very disenchanted with it.

Genericad is an engineering-drawing package with considerable extra drawing support in the form of packages of symbols, for example, which are available at about £39 pounds each. It has lots of facilities, and here I have to admit to having had only a short trial with it when not, perhaps, set up to its best advantage. If it has the support that you are after, give it a try, but the screen presentation for me was less impressive than Easycad2.

Both Easycad2 and Autosketch have on screen measuring and allow various plot options; also a DXF data-exchange option, which is useful for interchange of drawings between packages with similar support. Thus a main drawing office could use Autocad or Fastcad (see below) and be fed with drawings supplied by those using Easycad2 or Autosketch. Easycad2 has a much better set of drawing commands; its redraw screen updates three times faster and there is no question that it is the better package.

### Easycad2

Easycad2 offers a large range of commands, an ability to use script files for configuring the screen (see later) and a powerful method of selection for editing.

One criticism is the modest provision for seeing what happens after selection, although editing performance was acceptable. It allows drawing to grow without running out of space and still be printed on a single page, by use of a

### Operating environment

Although Easycad will run using a CGA screen, an ordinary PC and with only two floppies, this is less convenient than using an EGA screen and a hard disk. With a lower-resolution screen like CGA, more use has to be made of zoom and the work proceeds in smaller pieces. The desire for increased drawing speed, such as that provided by the use of a 286 or 386, will be found mostly when a screen contains a lot of detail, since it has to be redrawn for each update. A 10MHz no-wait-state 286 was acceptable, a 16MHz 386 better, but even more speed could have been useful for dense drawings. This can be provided using a maths processor, since this increases speed by between four and ten times.

First choice for output is usually a plotter, or a laser printer if only black and white is required, but a dot-matrix printer can be used. However, a dot matrix printer is the sort of thing hanging on most PCs and it is useful if this output is good enough for the notebook. Figure 5 shows a plotted version.

Fig. 1. An overhead transparency using previously designed symbols

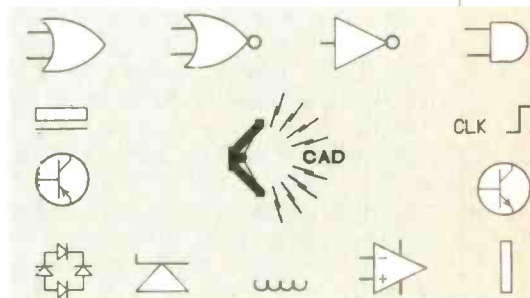


Fig. 2. The extensive list of available drawing commands. This is a dump of the query screen

FILE	VIEW	DRAW	EDIT	COPY	SPEC	MOD	CALC
about..	Redraw	Point	Undo	Copy	Select-by	Ref-Point	Coor
Help	Layers	Line	Erase	Repeat-Copy	Configure	Vertical	Brng
Status	Hide-All	Circle	Move	Circ-Array	Fill-Style	Horizontal	Dist
Label	Show-All	Arc	Scale	Rotate-Copy	Line-Style	Center	Area
Dir	Freeze-All	Ellipse	Rotate	Mirror-Copy	Values	Midpoint	
DOS-Cmd	Thaw-All	Text	Connect	Insert-Part	Text-Specs	Endpoint	
Menu	Background	Box	Mirror	Part-Array	Dim-Specs	On	
Script	Save-View	Path	Break	Circ-Part-Ary	Dim-Format	%-Along	
New	Pan	Polygon	Bend	Group	UNITS	Degree	
Load	Zoom-Win	Reg-Poly	Trim	Ungroup	Feet	Parallel	
Revert	Zoom-Cen	S-Poly	Stretch	Define-Symbol	Inches	Perpendicular	
Rename	Zoom-In	Spline	Text-Edit	List-SymDef	Meters	Angle-to...	
Save	Zoom-Out	Dimension	Origin	Explode-Sym	mm	Bearing	
Save-As	Zoom-View	Arrow	Fill	Replace-Sym		Tangent	
Plot	Zoom-Width	Dbl-Arrow	Front	Delete-SymDef		Intersection	
End	Zoom-Ext	Fillet	Change	Draw-Symbol			
Quit	Zoom-All	Chamfer	List				
	Zoom-Last	Tangent					
		Wide-Line					

scaling factor. Easycad2 derives from Fastcad, which was written by Mike Riddle after he parted company with Autodesk/Autocad. It was released originally as a sampler, but is well able to fulfil most drawing requirements.

Figure 1 was produced in a few minutes, using previously made symbols, as an example. Those on a tight budget or where time is not expensive can obtain symbols by several methods, as I explain later.

The Easycad2 package includes a well written 600-page manual. It is mouse-controlled, with alternative keyboard commands. Drawing data is stored in floating-point mathematical form, and picture size can change over an enormous range while shape is correctly presented when using a large amount of zoom-in. Easycad claims 'more than a million to one' as the ratio of the largest to smallest drawing entity.

## Screen presentation

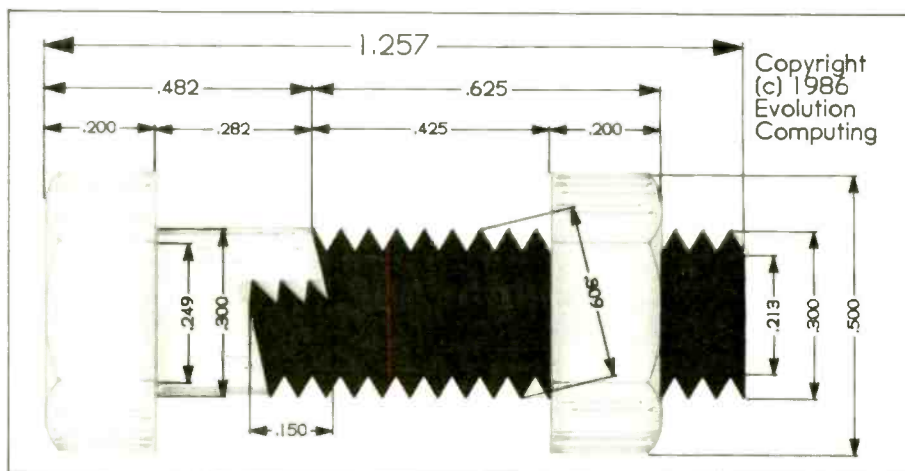
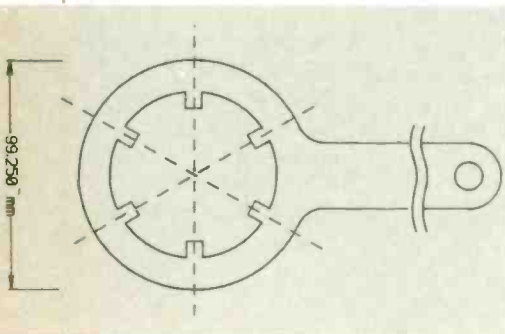
A line of menu headings across the top of the screen drop down as menu sheets when clicked on with a mouse. Each item explodes to reveal several more choices and you can find your way round the package fairly quickly, usually without reading the manual. Most of the commands are where you might expect them, though finding GROUP and UNGROUP under COPY might be unexpected.

There are no hot keys for COPY or MOVE, only the use of the menu. With so many different copy options such as rotate and scale, this is perhaps understandable. However, the fact that there are no hot keys at all was unexpected, although this was alleviated by being able to repeat operations using only mouse clicks.

## Drawing capability

The list of drawing commands is extensive, as can be seen in Fig. 4, which is a

**Fig. 3. Petrol-tank spanner, drawn by Easycad. Keyways were drawn at specified angles**



**Fig. 4. Specimen of mechanical part, automatically dimensioned by FastCAD**

screen dump of the query screen, a surprising number of uses can be found for this type of software. For example, a problem with obtaining a spanner to extract a petrol sensor from a car's petrol tank was solved using Easycad to make the drawing (Fig. 3) which was plotted by a dot-matrix printer, pasted on a piece of 4mm-thick steel and cut out; keyway angles were drawn using specified line angles. The whole process took less than an hour.

For the artistic, there are trick features like auto-repeating a drawing as the spokes of a wheel or as an array. This was how the artistic impression of radiating sound from the loudspeaker was drawn. Angled text and brick wall effects are also possible. Changing a drawing colour is just a click away, with the cursor on one of 15 colour pads at the left of the screen. This can be done in the middle of drawing a polygon, if need be, and each side can thus have a different colour!

The circuit diagram shown in Fig. 5 uses just a fraction of the drawing capability.

## Making a drawing

To make a drawing, you start by putting up a non-printable grid on the screen. Depending on what is being drawn, the grid values may need to be in feet, inches, millimetres or some other value and this facility is available; the screen zoom is infinitely variable.

The screen is configured by issuing commands or by running Scripts, which run like a batch file, either just before a new drawing or during the drawing. Any much-used sequences, such as grid size, font style or zoom, are written down and later put into a script file, but there is no questionnaire option to write the file automatically. A few such scripts for favourite configurations are very useful. Macros are also supported,

but were not tried. The plot can always be scaled to a convenient size.

## Editing

It is easy to select a part of a drawing; for example, to select a small circle which is buried in a mass of other lines or a word of text which straddles some part of the drawing. Using mouse clicks on the appropriate commands enables the stringing together of selection filters as required. Thus, at its most complicated, the selection can be made to depend on a Boolean combination: "If" is enclosed in a box, "And" is a line, ("Or" a circle, "Or" text), "And" is a certain colour, etc. On selection, a change occurs in the intensity of that selected.

Alternatively, a line is selectable by placing a box round the end of it; for example, round the upright of a "T" where it joins the top bar. Similarly, with a line of text. TRIM is an odd name for extending a line as well as shortening it. Breaking lines or circles into subsections is provided for, as is mirroring. Things can also be scaled, rotated. There is also an undo.

## Symbols

Of particular relevance to EW + WW readers is the availability or otherwise of circuit symbols. Support packages have recently been made available, but alternative means can be pursued to obtain them, either because such sources are cheaper or because they contain additional material.

Symbols can be imported via DXF, provided you can locate a DXF source. Not all symbols are so available; for instance, the Genericad ones are lower cost at £39 but, even after the purchase of the stand-alone Genericad conversion software, conversion DXF was not possible.

One can collect symbols by extracting

them from imported drawings. There are two ways of doing this: as symbols, they can be saved from the screen individually and go into a hidden file associated with that particular drawing. They are then made available generally by erasing the screen and saving the blank screen 'drawing' (to another file), which is then loaded as a PART over any new drawing to add the symbols to those already there.

Another method is to save the symbols individually as drawings. However, all the screen then has to be erased except the wanted bit; reloading and erasing may have to be done many times. Such drawings are imported into the drawing by calling them a Part. Symbols can, of course, be produced by drawing them, as in Fig. 1.

### Lack of fonts

There were no bold filled fonts, which are useful for making projector overheads, although outlined fonts were available as an extra, as in Fig. 1. A font-making package is available which uses lines and curves.

Fonts are, perhaps, something needing further thought; you cannot import them using DXF! One of the problems is that you can end up paying much more for the support packages than you did for the original software, particularly if the support is geared to expensive packages like Autocad.

### Hard copy

Easycad has considerable support for plotters and printers, even for laser printers, the printout from which is often superior even to a modern plotter such as the HP 7475. Plotters may offer a 0.1mm resolution, but the minimum pen size is usually 0.3mm and width can bleed. Finally, one can infinitely scale the hard copy output to a plotter or printer at plot time.

### Exporting drawings

Finished drawings can be converted to DXF, without entering the drawing routine and external DXF files imported and converted from AutoCad, Autosketch, or Fastcad. Several desk-top publishing packages now also accept DXF, including WordPerfect 5. Interchange could be important in the future, as old packages are discarded and new ones replace them. Old drawings may not be accessible or, at the very least, involve you in a laborious conversion process, dealing with drawings one at a time.

In this respect, screen grabbers can be used to store a bit image of almost

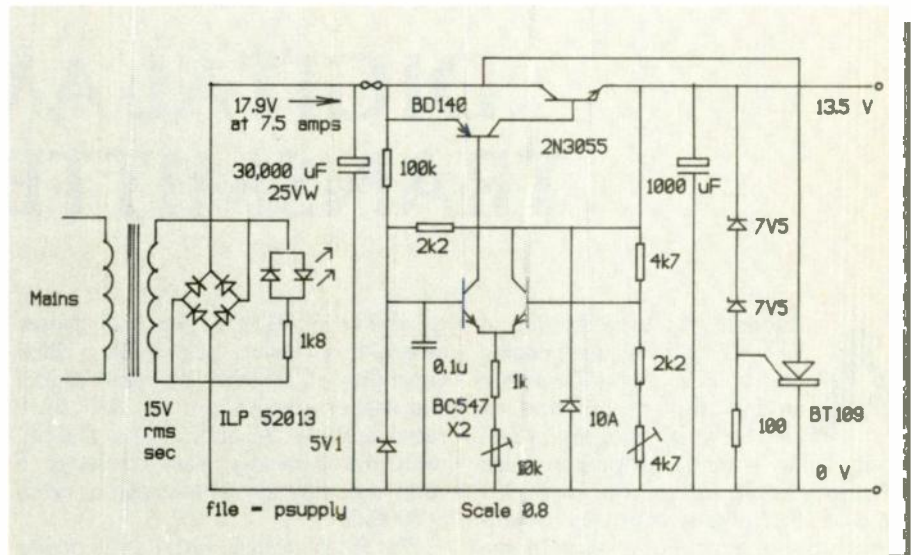


Fig. 5. Circuit diagram produced by HP7475 plotter

any screen, but few packages can go from there to a line-drawing format to allow manipulation along conventional lines; this always results in a loss of resolution. It should be possible to write a stand-alone conversion facility; already text readers capture a bit image and then work out what the alphanumeric characters are.

### Missing features

To summarize the missing features:

- there are no hot keys for the simple commands;
- scaling and rotation are available, but not in the easy form of 'select-and-stretch' which uses a box selection; some stretching in X or Y or both can be done, provided the part consists of straight lines;
- there is little visual support for what will happen, although there is an undo; some limited dynamic placements are possible but, unless you have a fast machine with a maths processor, this feature is best turned off as advised in the manual;
- wide line drawing is limited to straight sections, although various fill patterns are available; filling is available only for predetermined shapes and not for boxes constructed from individual sides;
- auto-dimensioning is provided, as on the spanner of Fig. 3, but is pretty useless because the values are taken from the screen and no editing is allowed; this will be corrected in the text release and meanwhile dimension arrows are available on a do it yourself basis;
- some screen messages are rather long — helpful for the novice, rather

over done for others, although they can be changed;

- there is no support for Postscript printers; this applies to many packages.

### Installation

The package came on three disks and installation was straightforward. It has been used with a laser printer, an HP7475 plotter and with 9-pin printers. The problems experienced in use were fairly minimal, with the exception of a bug whereby use of the mirror facility could sometimes cause a line end reference to be reversed so that trim acted the wrong way round.

### Conclusions

The package has been in use now for six months, with very favourable comments from six colleagues, and it is safe to conclude that this is a very useful package to have on a PC, whether it be for a circuit drawing, or for a part to be made in the workshop, or even designing your next house.

If this review is less critical than expected, this is because there is not much to criticize. A beta copy of a new version of Easycad2 which allows the editing of text dimensions was at the PC User Show and might be released later this year.

#### Supplier

Easycad2 is supplied by Polaron Controls Ltd, 26 Greenhill Crescent, Watford Business Park, Watford, Hertfordshire WD1 8XG. Telephone 0923 240272

The package costs £125 plus vat and Polaron can also supply the alternative text editor at £100 plus vat.

# DIGITAL AM TRANSMITTERS

**A**lthough AM broadcasting at LF, MF and HF has become relatively unfashionable engineering, it remains an area in which progress is still being made without attracting much attention. Exceptionally, the June 1989 issue of *IEEE Transactions on Broadcasting* took the form of a special issue on "medium-wave broadcasting". The guest editor, Donald J. LeVine, notes that much attention is currently being given to the application of the Method of Moments (NEC software) to MF antenna design and performance: "without doubt this is a tremendously valuable tool which has made broadcast (communications, radio-navigation) antenna engineering much more efficient and economical." But he insists that there is more to broadcast station and system design than the antennas: "heretical as this might seem to antenna design people."

He believes that a station designer must also consider monaural and stereo modulation characteristics, for example frequency selection, degree of automation, regulatory agency rule compliance and licensing obligations, studio or programme feed design, radiated-energy health and safety considerations and the environmental impact of the station and its radiated signals. For stations outside the United States, with signals overlapping international boundaries, "all the above problems or attention-gatherers become much more intense."

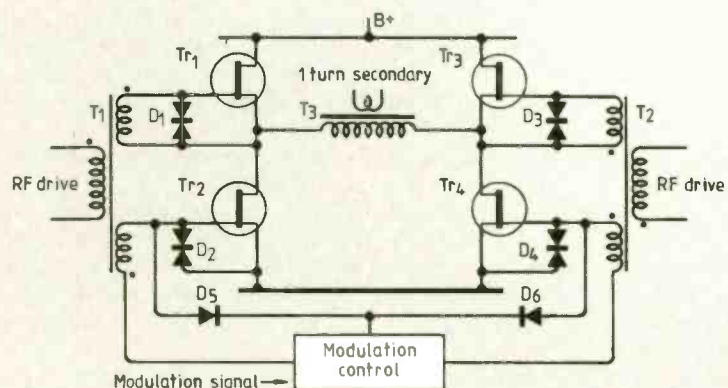
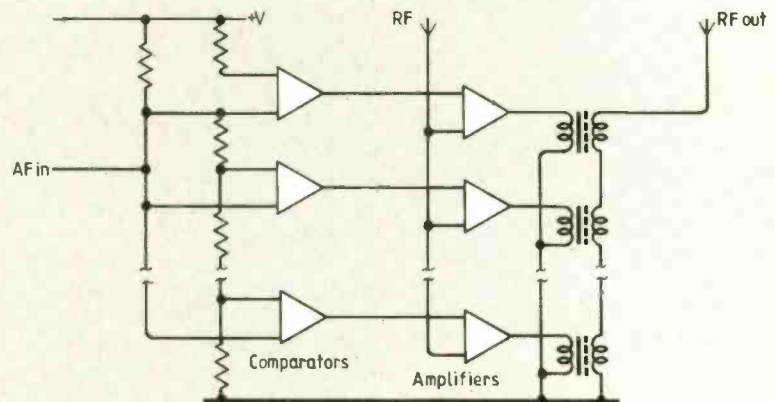
Technically, an interesting development reported in the issue by Hilmer Swanson of Harris Corporation is the marketing of a novel form of digital AM transmitter using a high-speed 12-bit A-to-D converter (with dither), a digital modulation encoder and a power multiplying D-to-A converter which reconverts the digital information back to analogue form. The result is a conventional AM signal with an overall conversion efficiency better than 80% and with power amplifier efficiency as high as 97% and a corresponding low rise in junction temperature. A 50kW digital AM transmitter with 150% positive peak capability and a peak envelope

capability of 312kW uses 123 power amplifier modules, each with a PEP capability of 2.54kW. The first digital transmitters introduced in 1987 were rated at 10kW. Apart from the DX-50, there are currently plans to design a solid-state digital AM transmitter rated at 2000kW.

The 50kW design, with its 123 power amplifier modules, has 123 voltage comparators which form, in effect, a flash A-to-D converter, and turn on the PA devices to provide the instantaneous output power requirement. During the negative-going peaks of the input signal, none of the PA devices are turned on. No high-power modulator is required; switching of the PA modules occurs at zero-current crossings. Hilmer Swanson points out: "The RF power capability of an amplifier, operating at medium-wave frequencies, does not

change whether the amplifier is digitally modulated or high-level modulated, because there is no additional stress or power loss in enabling or disabling an RF amplifier at audio frequencies. In the DX-line of transmitters, all of the high power amplifiers are enabled or disabled at an audio-frequency rate (the binary amplifiers are operating at reduced power)... For 150% positive peak modulation capability, the DX-50 has  $123/2.5 \times 49$  amplifiers on at 50kW carrier output. The power of each amplifier at this time is  $50/49 = 1.02$  kW. The dissipation of each amplifier at this power is 30 watts and efficiency 97%... junction temperature rise approximately 14°C."

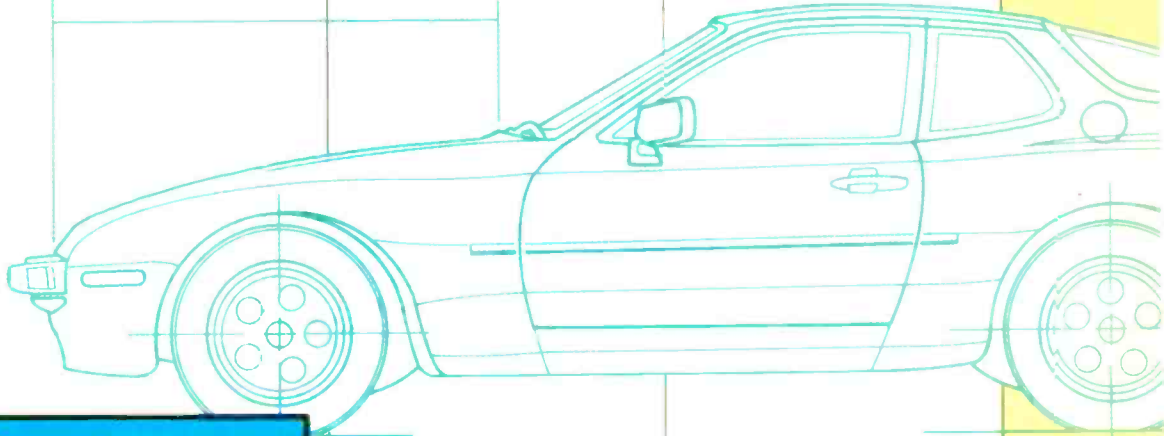
He believes that, with many digital AM transmitters showing reliable performance, they represent a step towards a completely digital broadcast station.





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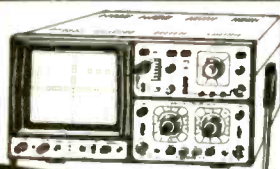
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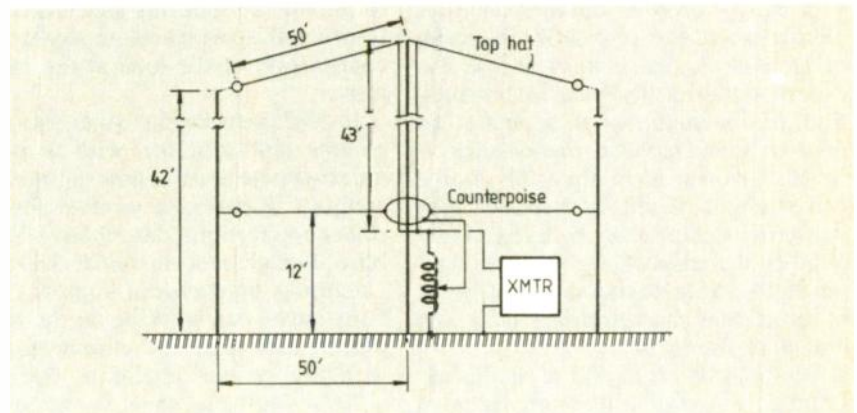
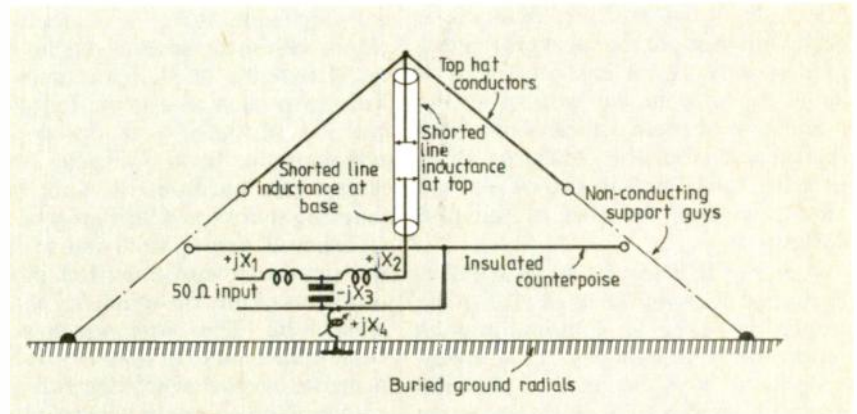
CIRCLE NO. 124 ON REPLY CARD

# Reducing mast height at MF

One of the major and most costly problems that face all users of the low and medium-frequency spectrum for broadcasting, communications or radio-navigation – as well as radio amateurs using the 1.8 and 3.5MHz bands – is achieving good ground-wave or low-angle sky-wave radiation efficiencies without the use of very high masts or towers and large number of buried radials. For many years a popular form of top-loaded MF antenna has been the so-called “umbrella” design in which a number of drooping radial elements fan out from the single central support, rather like guy wires, to provide top capacitance loading. Such designs do, however, require extremely good earth systems, often taking the form of 120 or more buried radials.

In 1973 Carl E. Smith and John D. Musselman patented a form of umbrella antenna using a counterpoise insulated from earth (US Patent no 3,742,511). This arrangement was used in Vietnam for a navigational system (260 to 535kHz) using a 35ft inflatable mast made by Goodyear; this achieved a radiation efficiency of the order of 67%. In 1974, the Smith-Musselman approach was used for a broadcast station, KVOK at Kodiak, Alaska using a 152ft mast and achieving an efficiency of about 92% at 560kHz.

Carl E. Smith has now described (*IEEE Trans. on Broadcasting*, June 1989, pages 237-240) a modified short low-loss AM antenna and explores ways in which the performance of relatively small transmitting or receiving antenna systems can be improved. He writes: “Small AM antennas are useful for standby use when the regular antenna fails for some reason. With some modification of a short tower by using top loading, low-loss loading inductances and an insulated counterpoise, the performance can be made quite acceptable. The counterpoise is connected as shown in the illustration. The inductance  $+jX_4$  is tuned so as to maximise the field strength radiated by the antenna into the far field... Top loading raises the current loop on the tower and, by adding a low-loss inductance at the top



of the tower, the current loop is raised still higher on the tower. A low-loss inductance at the top of the tower can be achieved by insulating a suitable conductor inside the tower and shorting it to the tower to simulate a short-circuited coaxial line with the open and inner conductor connected to the top loading hat at the top of the tower... At the bottom of the tower, more series inductance can be added by insulating a conductor up inside the tower to a shorting point. It may also be necessary to add a low-loss base loading-coil to resonate the top hat with the counterpoise... The counterpoise potential is adjusted to minimize ground losses.”

Dr James F. Corum of Corum & Associates Inc. believes that “The Smith/Musselman low-loss tuned-counterpoise structure is a remarkable addition to the technology of electrically-small antennas... it represents a significant contribution to this branch of antenna engineering. We

think that anyone requiring a vertical stub with an abbreviated ground system should seriously consider this technology.” It is clear from the paper that results are highly dependent upon correct tuning of the counterpoise system, preferably while observing the far-zone field strength. At the Corum test facility at Windsor, Ohio, a Smith/Musselman radiator resonating on 1330kHz had a tower height of 43ft, a top hat of 24 horizontal radials 50ft long, a counterpoise of 24-50 radials 12ft above ground and soil conductivity of 8 millimhos per metre, producing a field strength at 1 mile of 1.1mV/m with 250mW input with the counterpoise tuned, dropping to 605 $\mu$ V/m without the tuned counterpoise. ■

*RF Connections is written by Pat Hawker.*

## Simulating room acoustics for Archimedes

We live in an era where people pay hundreds of pounds for loudspeaker cables but then put the speakers right up to the walls. A lot has been learned about the way the ear works, but the interaction of room acoustics on sound reproduction has not yielded up all its secrets – and what is known has not always reached the ears of the hi-fi customers.

A recent IEE lecture by Laurie Fincham and Richard Small of KEF Electronics provided an interim progress report on "Archimedes", a Eureka-sponsored psychoacoustics research project (in which KEF are co-operating with Bang & Olufsen and the Acoustics Laboratory of the Technical University of Denmark). The aim is to use the experimental results from free simulation of listening room acoustics to improve sound reproduction systems.

This involves simulating the source and strength of reflected sounds in a standard listening room by using a large number of loudspeakers fed from a real-time DSP engine to simulate loudspeaker directional characteristics and room boundary absorption.

The objective is to add to the understanding of room affects on listeners rather than specifically to develop new products: "We want to know the scale of the problem; the variability between rooms is greater than the differences between loudspeakers. A good speaker in a good room, if kept away from the walls, is probably good enough for most people".

Initial tests are being carried out in the very large anechoic chamber of the Danish university (8m high, 10m wide and 12m long) while simulating an IEC-defined listening room (4.5 by 6 by 3m) in which it can be shown there may be some 99 sound images with time differences of less than 30 milliseconds.

The experiments are monaural: "We don't know enough about stereo... we are trying to assess the threshold of 'timbre' and 'spaciousness' on a variety of musical instruments". Listeners sit in an elevated 'cage' whose position can be varied in height above the floor but who cannot see where the loudspeakers are positioned". Each loudspeaker is fed with a signal of appropriate delay and amplitude.

## Beam indexing for small-screen TV

Colour television displays have always depended primarily on three-gun cathode-ray tubes with a beam-colour selection mechanism employing an aperture grill and shadow-mask to select the incident angle for the three beams.

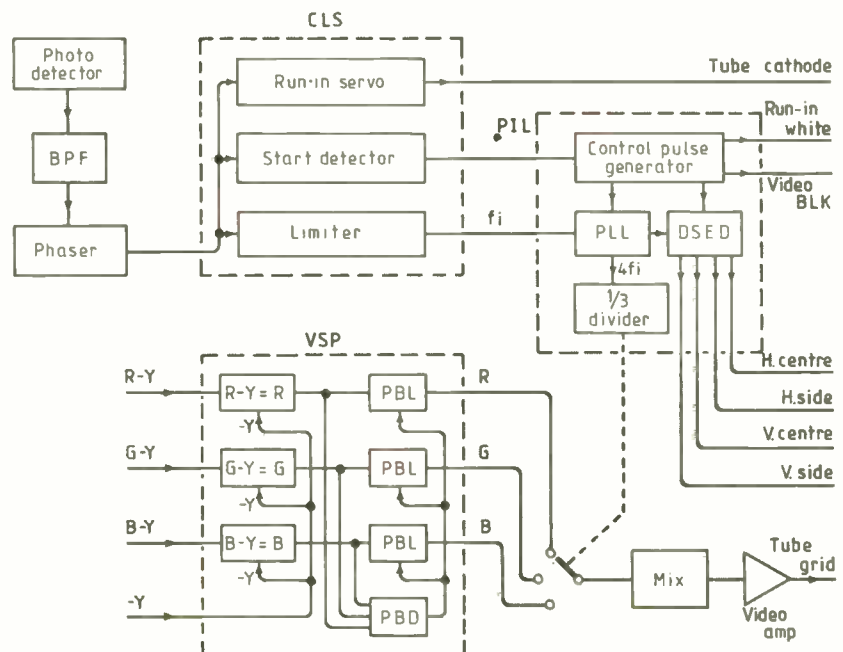
The once intensive search for practical single-gun tubes has largely subsided, with such names as Apple, Banana, Lawrence and Zebra tubes now little more than an obscure footnote in the development of colour TV, although the basic principles of the single-gun chromatron and beam-indexing tubes (on which most of these were based) turn up from time to time in the hope of overcoming the inherent problems of the low-efficiency shadow-mask tube. The basic principle of a beam-index tube is that it is able to generate a signal which depends on the colour of the phosphor being stimulated to provide an indexing signal arranged to switch the correct colour signal to the control grid of the tube at the correct time.

In 1987, Sony began to market a small commercial monitor with a beam-indexing tube and has now followed this compact beam-index receiver for consumer applications, described by Yoshihiro Shimada *et al* in *IEEE Trans. on Consumer Electronics* (August, 1989). Sony have been working on the beam-index tubes since the chromatron era with the serious intention, since the 1970s, of bringing them to the market with a view to exploiting their high-

brightness feature, low power consumption and their shallow depth. The new miniature receiver, based on considerable use of surface-mounted devices, has a screen size of 3.7-inches; luminance of 200 candela/m<sup>2</sup> (nit) (at 150µA); contrast ratio better than 50; resolution 150 lines; tube EHT 9.2kV; and power consumption 14 watts from a 12V DC power source. With a near cubical shape, the cabinet dimensions are 133 by 131 by 133mm. Because there are no geomagnetically-induced beam-landing displacement errors, it is claimed that the set provides a new level of ease-of-viewing as a "personal" or vehicle set, or as part of multipurpose products opening the way to new applications.

It has long been recognized that beam-index tubes require significantly more complex electronic circuitry than shadow-mask tubes; contrast ratio and colour purity are crucial problems, since there is no in-built colour selection mechanism. This means that, if the spot size of the electron beam becomes too large, the colour purity is degraded, since the spot will strike the wrong phosphors. It is thus necessary to restrict spot size and beam current.

Sony have developed special circuitry for horizontal linearity correction; for dynamic focus; for black-level current stabilization; beam-scanning speed control; peak beam limiter, comparator, limiter index process support (CLS); PLL index logic and other specialized requirements. ■



# TDS9090 Problem Solver...

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The TDS9090 measures just 100 x 72mm. One version has a DIN connector making it a shortened Eurocard. The other has pin headers for connection by ribbon cable, or use it as a component inserted on a larger board.

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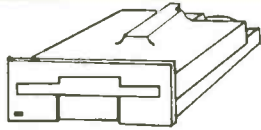
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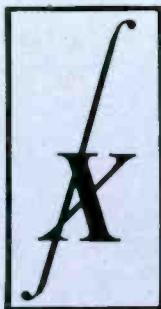
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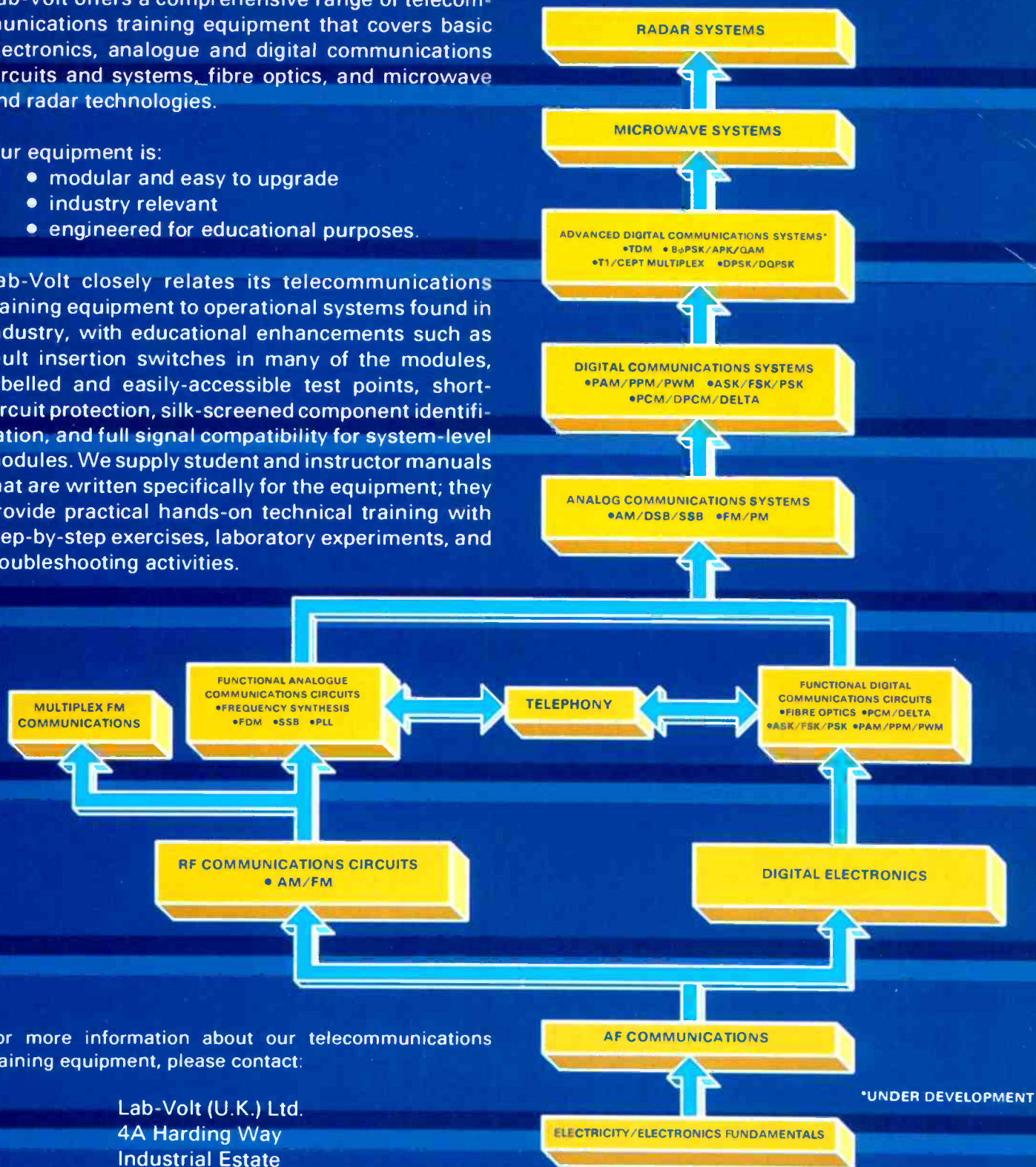
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