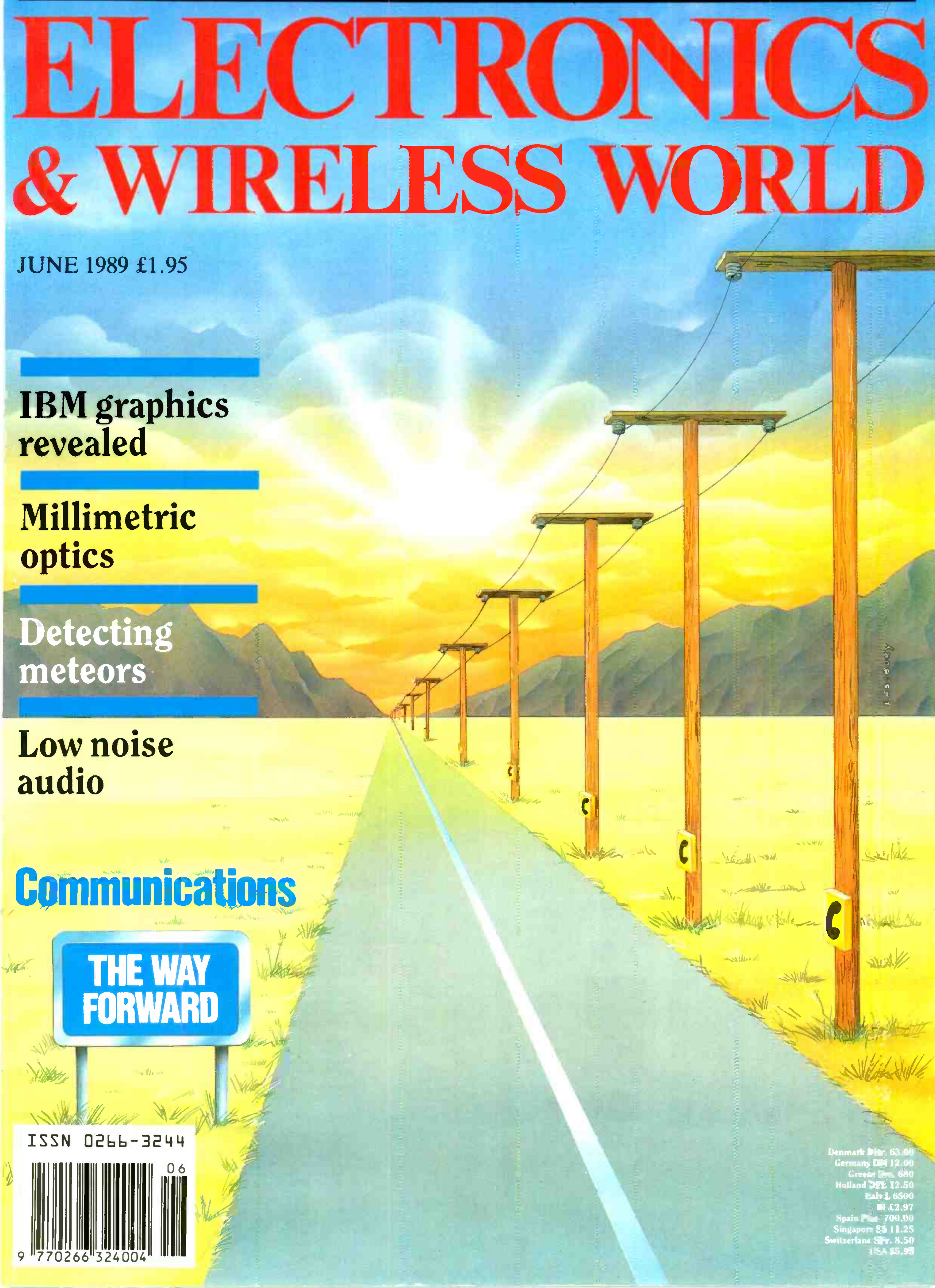
ELECTRONICS & WIRELESS WORLD

JUNE 1989 £1.95



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Low noise audio

Communications

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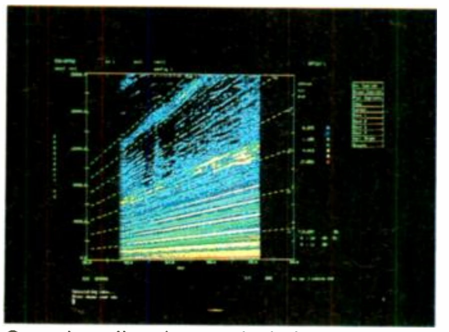
FEATURES



Complex vibration analysis is one area of research at Cranfield Institute of Technology – turn to page 553.

REGULARS

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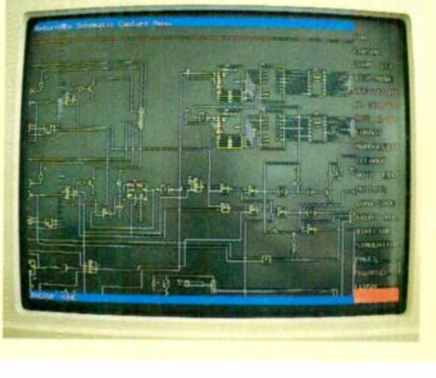
THE CAD REVOLUTION

Next month's issue brings you the definitive guide to electronic engineering CAD for the smaller company. There will be at least six IBM PC software reviews covering circuit modelling, schematic capture and PCB layout. We will also publish introductory articles on the use of CAD engineering tools.



Communications test equipment

Farnell Instruments Limited manufacture a wide range of test and measuring instruments for use with mobile radios, pocket pagers and other communications equipment. Instruments include synthesized signal generators, transmitter test sets, communications test sets, power meters, automatic modulation meters, frequency meters, etc.

Field portable units, bench or rack mounting models and complete systems are available. The latter are for manual use or micro-computer control via GPIB bus. Various software packages for standard measurement routines and self-test diagnostics are available. These allow non-technical staff to test complex communications equipment.

Designed and manufactured in Britain, a short form listing of Farnell communications test equipment follows. Further information is available on request.

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PSG520H	100kHz to 520MHz portable synthesized signal generator
PSG520	10MHz to 520MHz portable synthesized signal generator
PSG1000	10kHz to 1GHz portable synthesized signal generator
SSG520	10MHz to 520MHz synthesized signal generator
SSG1000	10Hz to 1GHz synthesized signal generator
SSG2000	10Hz to 2GHz synthesized signal generator
LA520	1.5MHz to 520MHz linear amplifier
TTS520	10MHz to 520MHz transmitter test set
PTS1000	1.5MHz to 1GHz portable transmitter test set
CTS520	100kHz to 520MHz communications test set
352C	Spectrum Analyser 300kHz to 1GHz

MODEL	DESCRIPTION
SGIB-B	GPIB (IEEE488) Interface bus for SSG520/TTS520 combination
SWIB	GPIB (IEEE488) 32 channel switching unit
F952	Power supply programming module for use with SWIB
0B1	GPIB (IEEE488) interface — non dedicated
0B2	GPIB (IEEE488) interace with A/D converter and digital panel meter non dedicated
TM8	Autoranging r.f. millivoltmeter 10kHz to 1Ghz+
AMM (B)	Automatic modulation meter 1.5MHz to 2GHz
TM10	Directional r.f. power meter 25MHz to 1GHz
2081	RF power meter
FM600(B)	Digital frequency meter 20Hz to 600MHz

Most models NATO codified

Send for further details of the complete range of Farnell test and measuring instruments.

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REED BUSINESS PUBLISHING

A surplus of electronics

The result of the latest study into satellite broadcasting by the TV manufacturer Ferguson will come as no surprise to the cynics. In short it says that satellite dish equipment sales won't even get near initial expectations. It now looks as though the industry will be lucky to sell a third of its expected first year volume, around 400 000 dishes.

The retailers naturally dismiss this pessimism; only time will tell if they are right even though history doesn't give them much support. Remember the great cable explosion of '84? Neither do I. A second look at the video film rental market would suggest to those of us who aren't market researchers that the public appetite for feature films is well catered for. After all, more than 50 percent of homes now include a video recorder among their consumer chattels.

A substantial number of homes have other bits of high technology cluttering up dark cupboards. What happened to all those home computers for instance? Gathering dust, having served their purpose. Ostensibly to satiate a public demand for arcade games in a safe first encounter with a microprocessor. Their consequence hasn't been totally meaningless. These machines educated and inspired a small minority of their users to seek new horizons beyond the space invaders. They harnessed their machines and the successors to industrial problems, medicine and defence. The same people were also in the vanguard of the electronic office revolution.

But most have simply put them back in the cupboard.

This is how the public generally perceives technology. Talking cars, electronic Filofax and washing machines with a brain the size of the universe. The true worth of consumer electronics has been minimalised to the point where it has become just another marketing gimmick.

This public perception won't assist the take-up of new consumer electronics services such as CT-2 cordless phones. These can make outgoing calls within a few hundred metres of fixed public base stations but lack the facility for accepting incoming calls: cf. cellular service phones now selling for under £200. It is an almost exact re-run of the video disc player saga. These playback-only machines were launched against a well-established video recorder market. They were first undersold and then virtually given away. They were built because the technology existed to build them.

Technology for technology's sake no longer works in the consumer market. Ignoring this fundamental piece of wisdom will result in large, white bird baths in front gardens throughout the land. And a cupboardful of high technology.

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A new meteor logging technique

Meteor trails are of interest to radio propagation specialists as well as to astronomers. This instrument can detect them even in daylight.

ANTHONY HOPWOOD

For thousands of years man has puzzled over the significance and origin of shooting stars. In past ages they were associated with comets and auroras as portents of ill omen. Today's astronomers still bracket meteor showers with comets, noting the similarity between the orbits of defunct comets and present periodic meteor showers.

These conclusions have been drawn from the painstaking analysis of thousands of individual meteor sighting reports carefully collated from all over the world. Despite the possibility of logging meteors by radio reflection and radar, the majority of sightings are still made by amateur observers who send their reports to organizations such as the British Astronomical Association for evaluation. In Britain, meteor watchers are at the mercy of the weather, which in late 1988 hid the maxima of four major showers behind persistent cloud, leaving a gap in the log. Any new and simple technique that can detect meteors through cloud or in daylight therefore has great potential.

For some ten years I have been designing and using electrometers to study the fine grain of the Earth's electric field. To gauge the performance of portable instruments in trials, I have maintained a regular watch on the ambient field using a fixed electrometer wired to a roof antenna and pen recorder in an upstairs room.

My interest in meteors was aroused in April 1988, when I saw a fine meteor cross the skylight over the recorder followed by a distinctive transient on the trace.

In August 1988, prompted by predictions that the Perseid display would be very good, I tried to observe and record it. Unfortunately, conditions at maximum were impossible, with heavy rain precluding all forms of observation. But next morning the sky was clear and sunny and so I started recording. At 0735 I detected a train of transients similar to the one I had seen in April.

There the matter rested until December, when the Geminids were also predicted to give a fine display. Over the Geminid period, I took some 50 hours of recording which, although visually unconfirmed because the sky remained obstinately cloudy, showed an increase in transients from the 'background' hourly rate of under 5 to over 100 during the run up to maximum **(Fig.1)**.

The Ursids on December 23 also showed a surge of transient activity beneath cloudy skies, so the stage was set for the Quadrantids, due to peak on January 3 **(Fig.2)**.

In the meantime, I had enlisted the enthusiastic help of Worcester amateur astronomers. This meant more pairs of eyes for visual corroboration, and the establishment of a second electrometer station in Malvern.

Eventually the sky cleared; and while recording 'background' during the evening of December 28, I saw a single meteor which also left its mark on the electrometer recording. This event also confirmed that there was a delay of several seconds between the visible event and the arrival of the signal on the antenna.

The Quadrantids duly arrived with another flurry of transient activity hidden by cloudy skies. The evening of January 4 was clear, however, and the combined observations at Malvern and Upton showed that out of 10 meteor sightings, no less than seven were electrically recorded.

ELECTROMETERS

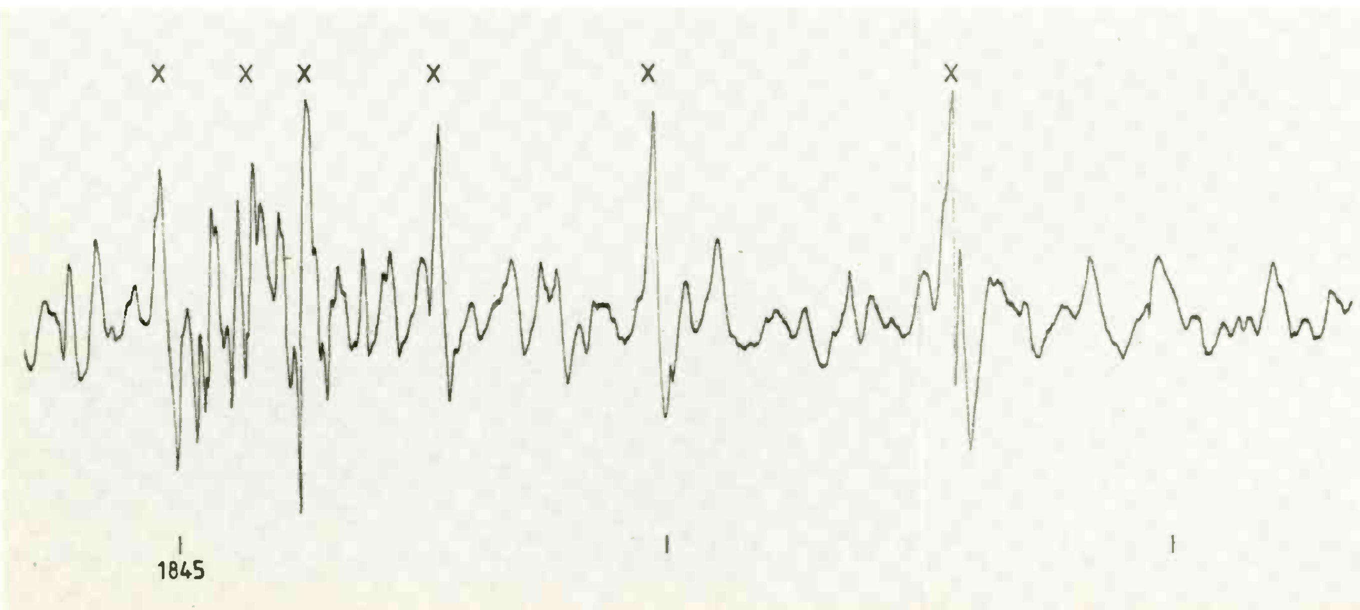
My work so far suggests that it is possible to detect meteors burning up in the ionosphere over a well-insulated antenna connected to an electrometer. So what is involved?

An electrometer is a very high impedance voltmeter which draws so little current that it can measure electrostatic fields and the ionization caused by smoke, radioactivity and high voltages. The instrument I use was specially built to monitor the ambient electric field and can accurately log atmospheric potentials because +350 and −350 volts **(Fig.3)**. It uses a single indirectly-heated 6Q7 valve in cathode-follower mode, free to float because positive and negative HT rails. A valve is used because it has the voltage range and can withstand kilovolt transients on the antenna during thunderstorms.

The electrometer has an effective input impedance of about 10^{12} ohms, and its output is drawn from the wiper of a potentiometer used as a cathode load. This allows the atmospheric DC signal from the antenna to be backed off so that it can be recorded at high gain by a DC servo pen recorder.

One major surprise is the way the system

Fig.1. Electrometer recording made on December 13, 1988, during the Geminid meteor shower. Range is 10V pk-pk; the markers below are at five-minute intervals.



'ignores' the mains-induced 50Hz wave on the antenna yet is able to sense millivolt atmospheric signals faithfully. Three factors are involved. Firstly, the recorder uses a mains frequency servo loop and so is geared to sense deviation from the algebraic centre of the waveform. Secondly, the mechanical frequency response of the recorder cuts off about 10Hz, so it naturally ignores mains transients caused by domestic appliances which alter the algebraic centre of the waveform too rapidly for it to follow. Thirdly, the induced waveform of about 15 volts peak-to-peak is symmetrically clipped at high gain to give a square wave signal whose mark: space ratio accurately reflects the DC excursions caused by electric field alterations.

The end result is a system well able to record atmospheric transients from a few millivolts to hundreds of volts peak-to-peak.

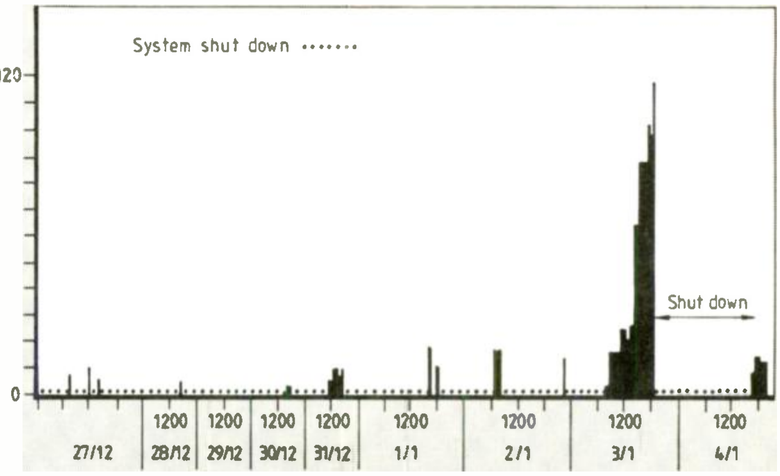


Fig.2. Electrometer transients during the Quadrantid shower 1988-1989, plotted as incidence per hour. Period covered was December 28-January 4.

EARTH AND IONOSPHERE

The classical description of the Earth/ionosphere system is that of a giant spherical capacitor whose outer plate, the ionosphere, is continually charged by the Sun and whose lower plate, the Earth, is insulated by the leaky lower atmosphere dielectric. The ionospheric charge shows as a normally positive voltage gradient averaging about 150 volts per metre above earth, but ranging from zero in fog to kilovolts during a thunderstorm[1]. This voltage can be monitored by an electrometer connected to a well-insulated wire or whip antenna.

My observations have shown that the effective atmospheric 'source impedance' varies between wide limits, from 10^{10}ohms to over 10^{20} ohms. The lower atmosphere voltage gradient alters not only with the condition of the ionosphere, but with water vapour and relative humidity. This variation in effective source impedance has led to problems with the simple wire antenna input to the electrometer. At times when the atmosphere goes 'high impedance', the antenna has too much capacitance to follow the relatively rapid variations in field caused by meteors. This often occurs on cold clear winter nights when visual confirmation of the electrical signal is wanted!

The problem can be overcome by replacing the 'passive' wire antenna with an 'active' short rod aerial fitted with a radioactive collector plate to improve the effective coupling with the atmosphere[1]. Ionization caused by the radioactive source improves the sensitivity by a factor of at least 100. Another, more conventional, option is to use a mosfet-input electrometer where the voltage gain makes up for the loss in collecting area of a vertical rod. The mosfet-input electrometer has the disadvantage that its operating point may need input bias adjustment and can easily limit or cut off if atmospheric conditions change.

Whatever input system is used, the input capacitance must be kept as low as possible. Any damping or averaging circuit is best fitted on the output. Nevertheless it is permissible to fit a low loss air-spaced 300pF variable capacitor across the input to double as a spark-gap and variable damping element (**Fig.4**). The mosfet can be further protected

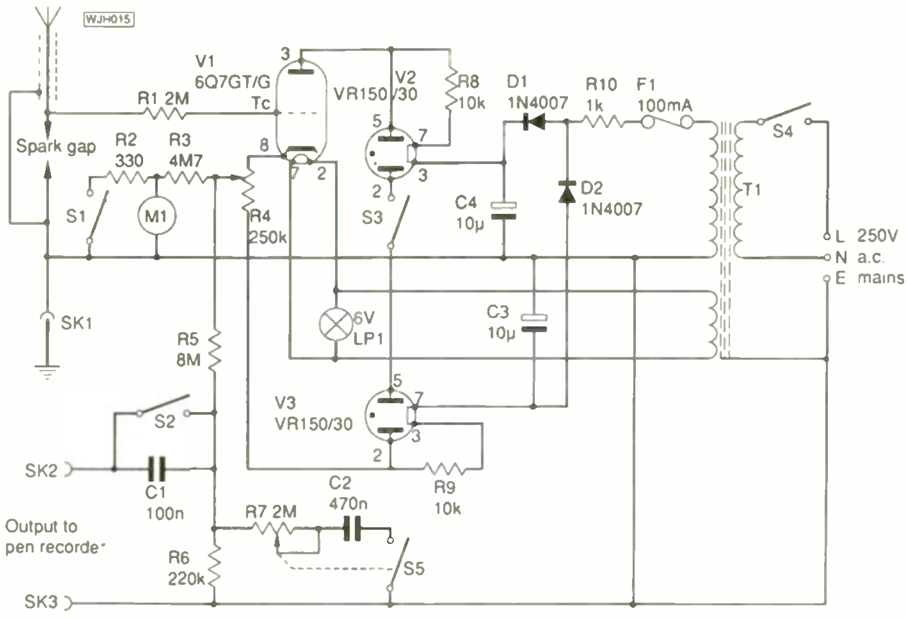


Fig.3. Circuit of the electrometer. It can accurately log atmospheric potentials in the range ±350V (by courtesy of the editor of *Practical Wireless*).

by wiring a small neon across it provided it is kept out of daylight because the ultra-violet component will turn it into a variable leak!

METEOR TRAILS

When a meteor burns up in the ionosphere, it leaves a short-lived, highly conducting ionized trail. This trail can be 'seen' by radar or radio because until it disperses it is an efficient reflector of short electromagnetic waves. Radar observations suggest that the average meteor leaves a trail some 30km long. These trails have been seen at up to 800km by radar[2].

A meteor trail forms a downward ionospheric projection which locally 'lowers' the ionosphere by many kilometres. The electrical effect is a temporary increase in the local electrostatic capacity as the effective atmospheric dielectric below is thinned. This causes a *pro rata* reduction in atmospheric voltage according to the simple expression $Q=CV$, where Q is the charge, C the capacitance and V the voltage; and it explains why meteor transients usually start with a negative spike. As the trail decays, equilibrium is restored by a balancing positive spike as extra ions disperse into the ionosphere leaving a characteristic transient on the recorder (Fig. 1).

It is likely that other mechanisms are involved, and a more complete explanation must await more data. Explaining why a small number of transients are recorded with reversed polarity is more difficult. A possible cause is a large or metallic meteor crossing the electrometer signal zone at a shallow angle above the electrical centre of the ionosphere. The strongly ionized trail would momentarily lift the charge plane causing an initial positive excursion of the surface electric field, followed by a negative recovery pulse. One important factor is that maximum ionization occurs before the meteor becomes incandescent[3]; the system may 'see' different events to a visual observer.

Observations on spacecraft suggest that meteors do not carry an appreciable charge when they enter the Earth's atmosphere because the solar wind and increasing ionization during re-entry rapidly strip off any surplus electrons as they heat up[3].

The intriguing observation that the signal takes several seconds to reach the antenna suggests that its propagation mode is electronic, and may be related to the 30km/s stroke velocity recorded for lightning. At this early stage, further verification of the exact relationship between meteor track and electrical signal by visual and other means is needed.

Validation of such a simple method of meteor observation will add many thousands of observation hours annually during daylight hours and under cloudy conditions, and will help produce a more accurate profile of meteor frequency throughout the year. It may even uncover additional showers that have been missed because they always occur during daylight. A more accurate meteor frequency monitor will be of real value to the growing numbers of radio amateurs who rely on meteor trail reflection to log distant stations.

There is also a commercial implication. With the growing numbers of manned space launches and permanent broadcast satellites, the probability of damage from meteor strike becomes of more than academic interest to those insuring commercial space vehicles. I am sure that further research will disclose how the shape and duration of the meteor signal can tell us its velocity, direction, mass and probable composition, and pave the way for a fully automatic 24-hour meteor logging system suitable for observatory and amateur use. ■

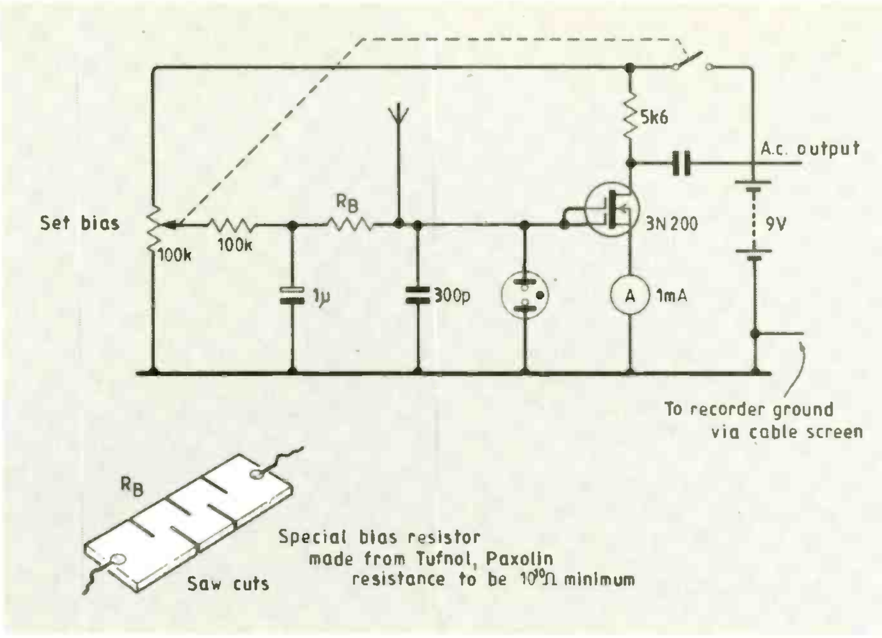


Fig.4. Simple portable electrometer. The bias adjustment is necessary to compensate for atmospheric changes.

References

1. Equipment for forecasting lightning danger, Paul B MacCready jr. in Recent Advances in Atmospheric Electricity, Pergamon, 1958.
2. Radio observation of meteors, J.G. Davies, *Advances in Electronics and Electron Physics*, IX, 1957.
3. Electrohydrodynamic properties of satellites, Lester Kraus, in Avionics Research: Satellites and problems of long range detection and tracking, Agardograph 40, Pergamon, 1960.

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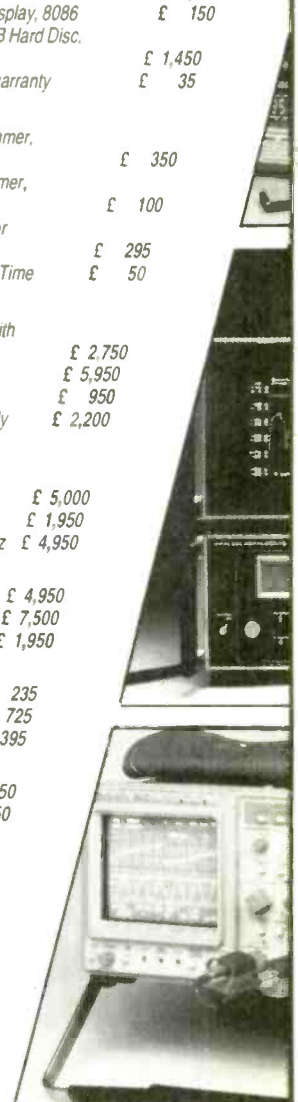

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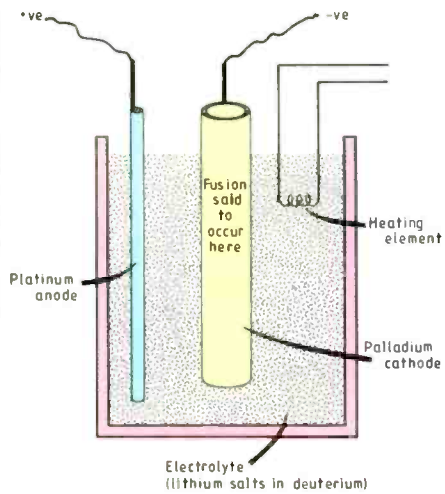
RESEARCH NOTES

H-bomb tamed in a test-tube?

At the time of going to press (and it seems to get earlier and earlier in spite of new technology) two electrochemists, one British and one American believe they have made a big step forward in harnessing nuclear fusion power. Up till now, in spite of 40 years of mind-boggling expense, the only way Man has been able to duplicate the energy-generating processes of the Sun has been in the form of H-bomb explosions – hardly very user-friendly.

Achieving the same process – fusing hydrogen atoms into helium – in a controlled continuous fashion would go a long way to solving the world's energy problems for the foreseeable future. Unfortunately, at least if conventional wisdom is to be believed, such a process would involve enormous pressures, stupendous temperatures or both. No-one seriously expects a practical power-generating fusion reactor to be commercially viable until well into the next century.

So what are we to make of an announcement at a press conference in Salt Lake City that Professor Martin Fleischmann of Southampton University and Dr Stanley Pons of the University of Utah have fused deuterium atoms, virtually on the kitchen table? Details are still somewhat obscure because there's been no publication in the scientific literature (Fleischmann and Pons say they called the press conference because their work was already being leaked).



Fusion or illusion? – the Fleischmann and Pons experiment.

What we do know is that the process involves an electrolytic cell in which deuterium atoms apparently fuse together inside a solid electrode made of palladium.

As with any seemingly crazy scientific discovery, what now needs to be done is to reproduce it with consistent results under controlled conditions. Such experiments are in fact under way at the UKAEA's Harwell Laboratories near Oxford and in about 100 other laboratories around the world. Scientists are not expecting dramatic results, nor are they planning, this time, to circumvent the normal channels of scientific publication. They also note that the earlier experiments were not all successful and that the effect was not always evident from the moment of switching on.

For those reasons they will be conducting a large number of experiments over a prolonged period.

Stop press. Researchers at the Texas A&M University in Houston claim, along with physicists in Hungary, Japan and elsewhere, to have repeated Fleischmann's and Pons's experiment. They haven't, however, detected any of the neutron emission that would be expected from the most obvious nuclear fusion reaction involving deuterium:

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + n + 3.2MeV$$

Other possible reactions might occur, but they too would produce radioactive decay products which would presumably also be detectable. The Texas team, like many others, is therefore still not ruling out some obscure chemical source for the observed excess heat output.

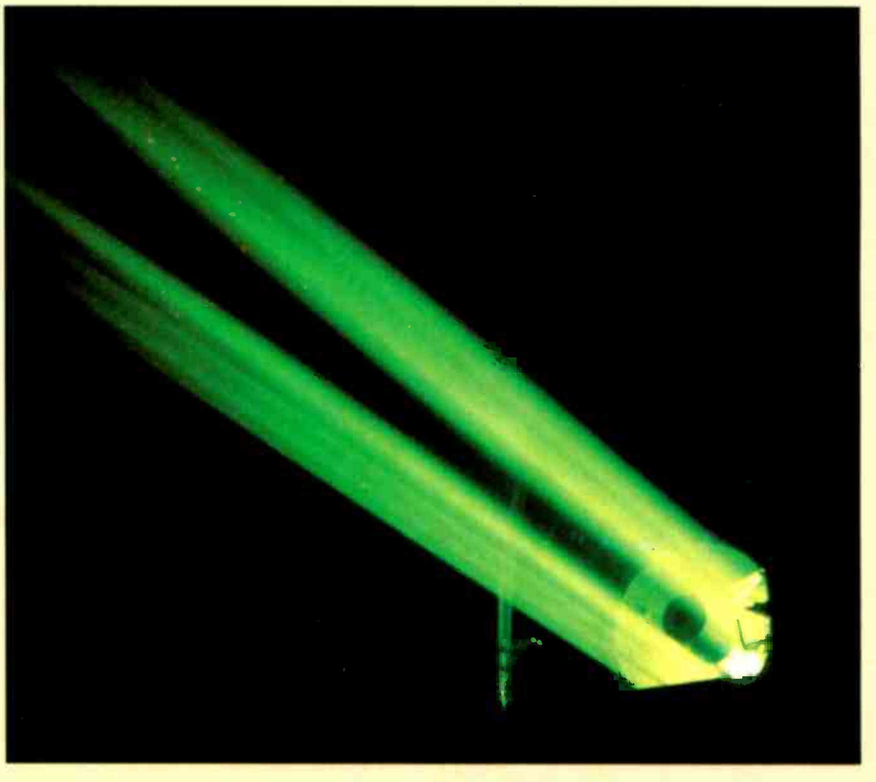
I personally would stick my neck out and suggest that until there is some positive demonstration of a phenomenon that has the authentic stamp of nuclear fusion, it's all a load of moonshine. And before I am branded as unscientific, I'd just like to draw your attention to the amazing lack of control experiments. Does it work with tap water? Or common salt? And why is it that none of the big research establishments like Harwell, MIT, Los Alamos, or Lawrence Livermore, has been able to re-create something to simple that even a schoolboy could do it? Watch this space!

Laser clock check

As time standards become increasingly accurate, clock synchronization around the world becomes correspondingly difficult. In an attempt to improve international synchronization, the European Space Agency has recently been experimenting with laser stations firing optical pulses at an experimental package fitted to the geostationary Meteostat P2 satellite. The package consists of two components: a passive reflector array and an optical pulse detector that registers the time of arrival. A combination of these features will allow laser stations in Europe and America to achieve a time reference accurate to within 10^{-9}s.

As yet the complete system remains to be tested, though some parts of it including the passive reflector are already yielding useful results. Initial tests involving the firing and receipt of laser pulses from a single ground station have, for example, enabled ESA researchers to measure the ground-to-satellite distance with an accuracy of 5 to 10 centimetres.

Right: laser ground station (by courtesy of CERGA/CNRS).



RESEARCH NOTES

Superluminescence

Getting power into an optical fibre has never been particularly easy. Laser diodes have the undoubted advantage of high output power and coupling efficiency but, being highly coherent feedback devices, are prone to noise. Light emitting diodes (leds) on the other hand suffer from poor output, poor coupling efficiency and excessive spectral width.

A hybrid device which seems to offer the best of both worlds has now been developed by a team working at the Compound Semiconductor Devices Center of the OKI Electric Industry Company of Tokyo. This superluminescent diode (SLD) is reported (*Electronics Letters* Vol.24 No 24) to have overcome the tendency of earlier SLDs to behave partially, at least, like laser diodes.

Conventional SLDs are in fact structurally very like lasers but with anti-reflection coatings where the mirrors would otherwise be. This in theory allows stimulated emission, but without feedback that can make a laser noisy.

The Japanese team says that it is impossible to make perfect anti-reflection coatings, so it's adopted a completely new type of structure so as to suppress any residual lasing action. In brief, it makes use of a buried active layer in a V-shaped groove on an indium phosphide substrate. This also incorporates a light diffusion surface to scatter backward emission from the active layer.

The practical device, which can produce output of 2.2mW at 1.3μm (infra-red), has a spectral width of 30nm, roughly a third that of a typical led. No lasing activity of any sort has been observed and the maximum modulation bandwidth (−1.5dB) is 350MHz. The Japanese team claims that its new device is a remarkable improvement that should widen the applications of single mode optical fibre transmission systems.

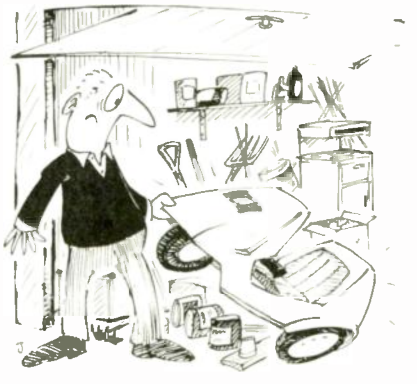
Electric vehicles – we're getting there

Electric vehicles, beloved of environmentalists, have never really caught the public imagination. True, there are fleets of delivery vans and a variety of other successful commercial vehicles, but where speed and range are paramount the internal combustion engine still reigns supreme. One obvious disadvantage of most electric vehicles is the so-called 'action radius', half the distance they will go on a single charge.

At the moment steady improvements are being made in lead-acid battery technology and in some of the more futuristic power storage devices such as the sodium/sulphur battery. But however much battery technology advances, it's unlikely that it will ever be possible to replace a full charge in the time it takes to fill up with 10 gallons of four-star. In this respect the greatest technical limitation is the rise in battery temperature during charging.

Just imagine, moreover, how much current you'd need to recharge fully a 150Ah battery in one minute. The average set of crocodile clips might just be turning cherry-red!

A one-minute charge probably always will remain a pipe-dream, but a one-hour top-up now seems a realistic possibility according to research being undertaken at the Swedish Institute of Microelectronics. Experiments there used a 143Ah lead-acid battery in which each cell contained a cooling coil encased in plastic. The idea was to circulate cold water around the coil and extract the excess heat produced by fast charging – a sort of domestic hot-water cylinder in reverse.



In the course of these experiments the Swedes found that if cold water was circulated at a rate of 1l/min, they could perform up to five charge and discharge cycles in eight hours. What's more, the battery would reach its full charge with 95% efficiency.

To get the fastest possible charge, it was found necessary to vary the charge rate to accommodate the changing internal resistance of the battery. This rises considerably as the battery approaches full charge. The Institute found that an initial charging current of 150A gradually reducing to 50A ensured a more-or-less constant thermal dissipation within the battery.

This experimental work, which also extended to nickel-iron batteries, has considerable implications for the development of electric vehicles. For while it doesn't quite lead to the convenience of petrol, it does offer the possibility of taking on board substantial amounts of power during breaks in service. The opportunity of a quick charge during the lunch break would, for example, double the daily range of any given vehicle.

The Swedish team also envisage track-bound vehicles such as trolley-buses and trains in which the supply lines are placed only intermittently along the route. Just imagine the convenience if pantographs or third conductor rails could be omitted through tunnels or over complex junctions. Imagine also the safety benefits of keeping conductor rails away from stations or of a train that is capable of reaching the next platform during a power failure.

Silicon sands of time

Classical metaphors for numerical magnitude may soon undergo a revolution if the semiconductor industry keeps up its present momentum. Current guesstimates suggest that the number of transistors in a typical household may well exceed the proverbial hairs on our heads. And while this burgeoning bipolarity doesn't have quite the same poetic ring as its biblical predecessor, it does make one stop and think.

According to Gordon Moore, chairman of the Intel Corporation, 1988 saw the creation of some 10^{15} individual transistor junctions – more than had ever previously existed in the whole world. This rate of growth, which has been kept up for many years, can be translated into an average annual consumption of four million transistors per household in the developed world. It will moreover, according to Moore, double this year and double again in 1990. What use, I wonder, will you be making of your eight million.

Taking the heat out of temperature

From January 1, 1990, water will no longer boil at 100°C – and that's official! It's all a consequence of standards revision by the International Committee for Weights and Measures and takes into account advances in both theoretical and practical thermometry.

The first international scale was agreed in 1927, only to be revised in 1948 and 1968 to take advantage of the greater number of reproducible fixed points. The latest scale, known as ITS-90, extends the process further taking into account everything from helium vapour pressure equations (relevant at 0.65K) to radiation pyrometry at and beyond the freezing point of gold (around 1337K).

Because various different techniques have been used to establish these fixed points, there's been the inevitable problem of what happens if one measurement technique is recalibrated in any way. Shifting one point on a temperature scale is a bit like giving a small nudge to the middle of a taut piece of string; it affects the position of virtually every point along its length.

ITS-90 no longer uses boiling points as primary fixed points because they're not as accurately reproducible as freezing points or various other physical parameters. Time-honoured values, like the boiling point of water, are therefore subject to the pull of linearizing influences elsewhere on the scale and will accordingly be revised to reduce errors of interpolation.

From the beginning of next year a properly calibrated thermometer immersed in pure boiling water at standard atmospheric pressure will read 99.975°C.

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

1992 and beyond

The communications industry's support for the single European market was among topics discussed at this year's conference of the Mobile Radio Users' Association.

RICHARD LAMBLEY

Britain's mobile radio is the fastest-growing industry in Europe. After the explosive growth of the last few years this might have been a time for it to take stock and consolidate its recent achievements. But a series of presentations on the first day of the conference concentrated attention on the imminence of 1992 and the single European market.

Stephen Temple, of the Radiocommunications Division of the DTI, emphasized the point: "From 1992, Britain's home market, which today is Manchester and Glasgow, will tomorrow be Turin and Stuttgart". Preparation of the infrastructure to support the consequent expansion of business activity needed to begin now, he said. Temple, who sits on the EC's RACE management committee and is chairman of the European Technical Standards Institute, reviewed a number of European developments in the radiocommunications field.

NEW RADIO SYSTEMS

GSM (the all-digital pan-European successor for national cellular radiotelephone systems such as Britain's TACS) was, he said, the cornerstone of the industry's preparations for 1992 and had become a model for other European initiatives. Frequency managers had identified the need for it and had started the planning process almost ten years ahead of the implementation (opening is set for 1991). Such forward planning was the key to successful spectrum management.

CT-2, the cordless telephone system shortly to make its public appearance in Britain, now seemed to have caught on abroad thanks to the common air interface agreed by British manufacturers. "By June we may have a four or five-country agreement", said Temple. He saw CT-2 as occupying a gap in the market which would exist between cellular and DECT, the forthcoming digital European cordless telephone: to begin with, DECT would be expensive and pitched at cordless PABX applications rather than at domestic or consumer use.

In wide-area paging, frequency managers were not so far ahead of the game. The EC had proposed a directive on channels for a pan-European paging system at 160MHz, to be known as ERMES. But an interim common service was likely to begin on 466MHz in France, Italy, Germany and the UK in the next 12-18 months. Many people had asked whether this was simply a spoiler for ERMES, but in fact it would stimulate the market for it. A problem was that different markets were developing at vastly different speeds.

Another new system was aeronautical public correspondence (in plain language, telephones fitted to passenger aircraft); British Airways was already running trials on its shuttle services, using the 1.5-1.6GHz band. But ETSI would tackle the question of international standards. In the short term, this would mean a pay-phone-like service, but two-way calling could become possible later. Europe should consider integrating this system into a larger network such as GSM or telepoint.

On the air soon: Ferranti's Zonephone is one of the two handsets which will launch CT-2.

RADIOTELEPHONES

Looking at the economics of communications networks, Temple commented on the very rapid growth of cellular telephones in Britain, where subscribers have just passed the half-million mark, as compared with Germany. He attributed this to competition in Britain between networks, equipment suppliers and service providers. "The whole cake", he said, "is five times bigger". Germany and France were now following the British example and introducing competition, and others were likely to follow.

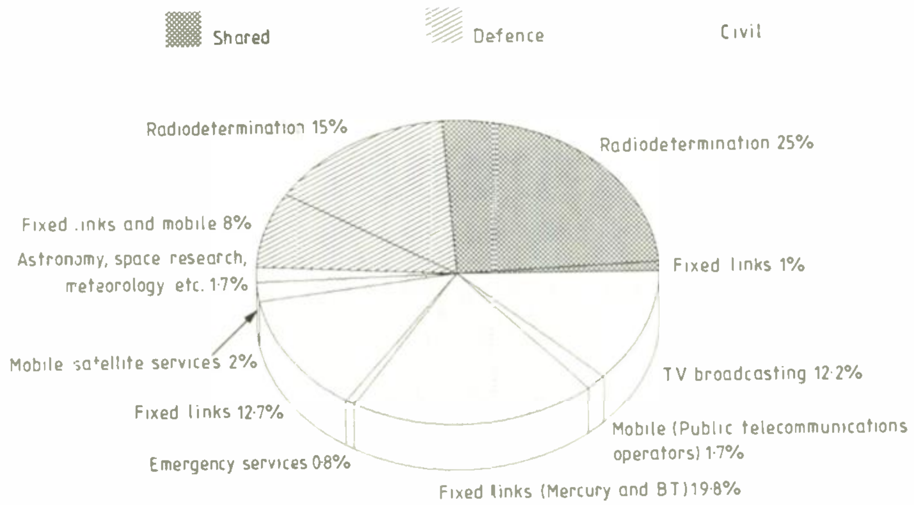
In Britain, however, dissatisfied cellular users in the congested city areas might well argue that the systems had been *too* successful. Good news came in an address to the conference by Robert Atkins MP, Parliamentary Under-secretary of State for Industry: "We will be making available 120 additional channels in major conurbations outside London and along the major trans-

Last year's consultative document from the DTI on ways of using the millimetric waves drew 41 responses Some of the early applications suggested by the industry are listed here. One millimetric operator already active in the UK is Mercury Communications, which by March 1989 had installed about 75 2Mbit/s links in its 49.2-50.2GHz assignment.

General	***Broadcasting***
Around 60GHz – short range applications with intensive frequency reuse	Outside broadcast services
High speed radio lans	M^{3}VDS at 40GHz
Communication between buildings with line-of-sight	Electronic news-gathering equipment at 40GHz
Low cost medium to high capacity point-to-point and radial point-to multipoint distribution links for data, speech or video	47-49GHz for feeder links
CCTV	***Military***
Local area multipoint telemetry schemes	SMART munitions
Final connection in PTO network to customers, in oxygen absorption band	High definition battle-field radars
Radiometric temperature measurement	TGSM (Terminally guided sub-munitions) at 94GHz
Use in oil industry to communicate between fixed platforms and semi-submersible rigs or other vessels stationed alongside	Air surface movement indicator radar (ASMI)
Radioastronomy in selected bands between 30GHz and 50GHz	***Space***
	Inter-satellite links at 60GHz
	Aeronautical satellite communications

port routes". These extra channels, 60 for each network, are part of the 400-channel ETACS block released earlier by the Ministry of Defence for use in London, and should just about carry Cellnet and Vodafone through to the launch of GSM. Nevertheless, the MOD can at any time bar the extra channels by telling the networks to switch them off. Since call set-up is organized over the standard TACS channels, this action would simply result in greater congestion.

A major topic of the Minister's speech was piracy. "The public perception of radio piracy as harmless fun needs changing", he said. "Pirate radio has disrupted the mobile radio equipment of the police, fire brigade, gas and electricity services. If these services could not respond to emergencies there would be, quite rightly, an outcry." Pirates had even interfered with the new business services in Band III. "I want pirates stamped out, and I hope you will keep up the pressure on me and other MPs."



Despite the widespread impression of wide-open, empty spaces in the Defence bands, only 26% of the spectrum between 470MHz and 3400MHz is exclusive to Defence users. Principal civil and military uses are shown in this chart (Mike Goddard, DTI).

SATELLITES

Despite some attractive-looking frequency allocations, satellite services for the private mobile radio industry had not yet quite taken off, according to Dr Keith Shotton, who led the large DTI contingent at the conference. But a speaker from Inmarsat, Bob Phillips, described the land mobile services which will soon become available from the international co-operative following amendments to its constitution. Spectrum in the 1.5-1.6GHz band had now been reallocated to support such a service.

Inmarsat's first product specifically for the land mobile industry will be derived from its Standard C marine system and will be a 600bit/s two-way messaging service. This will use compact upward-looking antennas (no steering is required) and portable PC-based terminals. But Inmarsat was developing a telephony service based on 4.8kbit/s voice coding and was working also on a half-rate version of the 13kbit/s GSM system. In this way, satellite communications could be integrated with GSM's UHF service to produce what another speaker, Dr Stephan Pascall of the EC, called the Heineken of radio systems – it would reach the parts other radiotelephones could not reach.

The Forum Personal Phone is the CT-2 handset designed by Shaye Communications.

CIVIL SPECTRUM REVIEW

Mike Goddard, head of the DTI division concerned with frequency planning, discussed some of the ground covered by his department's recent review of the 470-3400MHz range. He avoided dealing with the finer details, saying (with the recent Lonrho-Harrods affair in mind) that the DTI had become a little sensitive about unpublished reports.

The review was essentially a backward-looking affair, an audit, but it would lead to a shopping list of requirements for five, ten, fifteen years ahead. Frequencies up to 1GHz would remain more or less unchanged because there was little chance of moving the large television broadcasting allocation. But an international review of the 1-3GHz band was expected soon, and a there was interest in accommodating new services such as personal advanced radio service (PARS) and a digital sound broadcasting service. There was also the possibility of CT-2 outgrowing its initial 4MHz-wide allocation. Full details of what changes might be made would be set out in the report, to appear shortly. ■

The MRUA's sixth annual conference was held in mid-April at Exeter College, Oxford. A set of papers is available at £25 from the Mobile Radio Users' Association, 28 Nottingham Place, London W1M 3FD, tel. 01-400 1518. Other topics covered by it include PMR applications in aviation and road fleet management, trunked systems, mobile data communications, and training for mobile radio technicians.

Italian Inmos

British chip maker Inmos has finally been taken over, by the Franco-Italian semiconductor combine SGS-Thomson Microelectronics, some ten years after its creation.

Entertainment-to-electronics group Thorn EMI swapped Inmos for a 10 per cent stake in SGS-Thomson. The company was founded with Government money and was acquired by Thorn in 1984 for £125 million.

SGS-Thomson's boss Pasquale Pistorio is promising further investment for Inmos and its transputer parallel-processing chip. He moved swiftly to allay fears for the future of the company by spelling out his plans just two days after taking control.

"Financial resources will not be a limiting factor to the growth of Inmos," he pledged.

Pistorio explained his wish to build a European semiconductor company that will ensure that Europe is independent of Japanese and American chip technology. Acquiring Inmos gives SGS-Thomson a 32-bit transputer microprocessor.

Pistorio called the transputer concept the "number one" reason for taking over the company. He said that faster versions of the chip will be developed and that Inmos' chip factory in Newport will be upgraded and that more than 100 extra engineers will be hired during this year.

The Inmos processors are designed so that any number of them can be strapped together to make powerful parallel computer systems. They contain an integer processor, a floating-point processor, local memory and on-chip communications links. The communications facilities provide the key to ease of use.

Most powerful cisc processor yet

The launch of Intel's 486 processor marks an evolutionary milestone in the development of the humble IBM PC. The 33MHz version will deliver a claimed 20 Vax mips of performance, at least three and a half times that of the best 80386 powered machines currently available. It will give a massive performance boost to all the software currently available in the dos market, currently estimated to be worth $16 to $20 billion.

The 486, which has complete downwards compatibility with existing dos and OS/2 software releases, includes a full floating point 387 co-processor, 8K bytes of static cache, cache controller, DMA with paging and a high-speed integer instruction decoding unit on a single chip. It claims a floating point performance of 49 dhrystones, a figure comparable with risc-based Unix chip sets.

The first release running at 25MHz clock will be available towards the end of the year in commercial quantities.

It uses 32-bit internal architecture with 32-bit address and data buses. A five-level pipeline which forms part of a risc integer instruction decoder runs frequently used instructions in a single clock cycle. A burst data transfer mechanism allows four 32-bit words to be read from memory to keep the on-chip cache and instruction queues filled.

Intel has adapted the memory management and paging facilities to match those of its other new processor chip, the 860. A few additional chips hung around the bus will enable multiprocessing systems to be built using a mix of 486 and 860 devices. The company expects this to be used in power Unix multi-user machines.

860 graphics supercomputer

One of the first applications to emerge for the new Intel 860 processor uses a transputer chip in tandem. The result is an add-on graphics accelerator for AT-compatibles with a power associated with a Cray-1. It is also British.

The Flute graphics/processing module will expand the computing and display capabilities of a standard business desktop PC to a level "which exceeds the fastest Sun, Vax or Mips workstation" says the Felixstowe company Tektite.

Paper processor

Motorola has outlined the architecture to be used on the next generation of 68000 32-bit microprocessors, having been stung into action by the succession of recent Intel micro announcements.

Unlike Intel's chips, the 68040, software compatible with earlier 68000 devices, is still at the development stage and isn't expected to appear before autumn. When it does, it will integrate a total of 1.2M transistors.

Gallium arsenide takes off

The increase in non-military GaAs applications for such things as logic chips and optoelectronics will quadruple US sales of devices made with the technology, says a new study by New York analysts Frost & Sullivan.

It claims that GaAs must increasingly be recognised as a mainstream semiconductor technology, although density limitations and higher material and fabrication costs will continue to exclude it from bulk memory and other high-volume silicon-type applications. The growth areas will use the higher electron mobility of the material compared to silicon which allows higher clock rates and access times in digital systems and higher operating frequencies in microwave applications.

Advances

Maximum capacity, minimum price and fastest data processing can be found in the latest crop of machines for in-circuit logic testing.

During the 1960s, engineers working on computer equipment found that existing measuring instruments were inappropriate for systems producing non-repetitive signal patterns and the first logic analysers were conceived. These were add-ons that turned an oscilloscope into a multi-channel instrument capable of displaying timing relationships between several signals.

In the next decade, analyser manufacturers developed the concept of data-state analysis which involves displaying digital information in terms of data values against machine cycles rather than individual signal-point levels against time.

Since about 1975, when the first combined state and timing analysers appeared, the logic analyser has not changed a great deal conceptually; it has simply evolved. There have been significant increases in the number of channels available, acquisition speed and triggering sophistication.

One feature of logic analysers that has not changed a great deal is the price of the cheapest instruments. Generally, the lowest price complete analysers still cost around £3000. According to John Nichols, technical director of Thurlby Electronics at Huntingdon, the low-cost logic analyser market is quite small and almost saturated which could explain why bottom prices have not fallen a great deal.

So why has Thurlby decided to introduce a logic analyser at under £1000? Nichols says that the market could be expanded a great deal if only engineers in small and medium-sized companies knew the advantages of logic analysis.

Even now, logic analysers remain a bit of a mystery to many engineers. With prices at £3000, there is little incentive for an engineer with a small budget to learn about logic analysis; but given a completely self-contained instrument costing under £1000, that could change. Thurlby's challenge is to expand the low-cost analyser market through education; unless it can do that the product will fail – but Nichols is very confident.

The £898 Thurlby LA3200 is a 32-channel analyser that can operate at acquisition speeds up to 100MHz. Its 48-channel counterpart, the LA4800, costs £1195. Both have

in logic analysis

a footprint half the size of any other analyser and a bigger screen than comparable units and their screens are graphics/text liquid-crystal devices with fluorescent backlighting so they can be read even in bright sunlight.

Cost has been kept low mainly by using off-the-shelf components. Two c-mos 6803 processors control the instrument – one acquires data while the other handles the user interface – and the logic ICs and memory are advanced high-speed c-mos parts. There have been few compromises with the software. On-screen help, comprehensive menus and data search/compare facilities are all standard.

Triggering facilities include multi-level triggering with if-then-else sequencing and multiple delays via event or clock counts. It is also possible to select full-width start/stop trace words for data qualification.

There are various optional pods for the analysers ranging from a three-channel clock-input unit at £49 to a 68000 pod with built-in disassembler software at £345. Included in the range are a 16-channel general purpose pod that allows glitch capture down to 5ns and six disassembler pods for 8bit processors.

Up to four 96-channel analysers in one unit

At the other end of the price scale is Gould's CLAS4000 at around £20 000. Being modular, the 4000 can be configured for anything from general-purpose high-speed analysis to a design tool for wide-bus multi-processor computers and complex asics.

There are many options for the 4000 but basically it can be configured as from one to four independent logic analysers with up to 384 channels and for data capture rates from 200MHz to 1GHz.

Instead of developing a user interface for the 4000, Gould has chosen to send captured data to a Mac computer, included with the system, via an SCSI port. Apart from decreasing development costs, this move increases flexibility by allowing custom post-processing data and it provides a proven user interface with windows and mouse control. With a 19in high-resolution monitor, the Mac is capable of displaying more than 50 timing waveforms at once. Gould plans to develop Mac based tools for the design engineer.

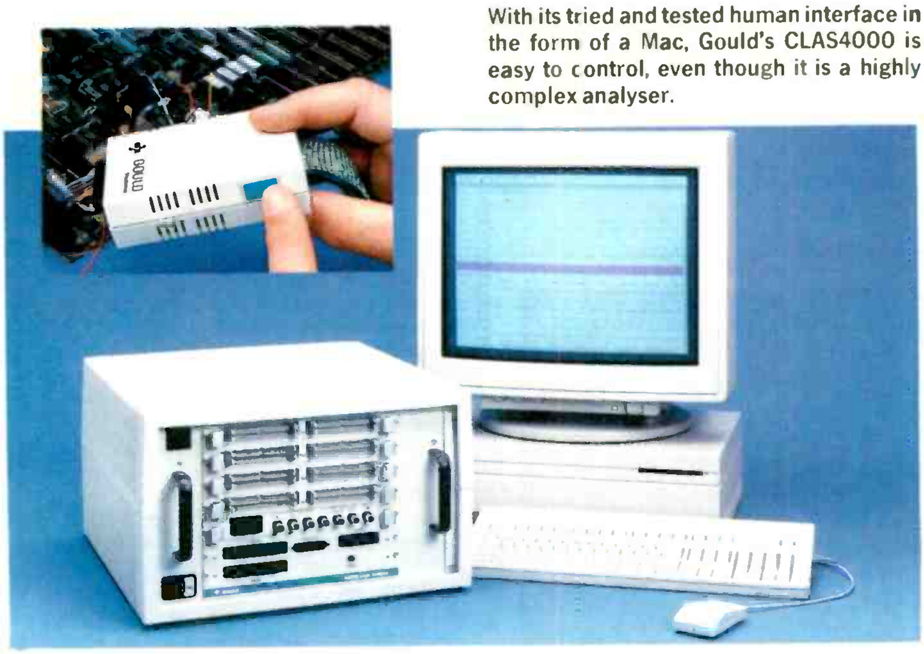
Resolution of the 4000 depends on the number of channels used. When 96 channels are needed, resolution is 5ns but for 64 channel operation, resolution rises to 1ns.

The 4000 has a number of facilities for simplifying measurements. For timing verification in, say, asic design, there's an accessory called Design Ruler, and probe assignment, trace control and external clocking functions are all done in graphics.

Colour windows – up to 16 of them – contain instrument configuration, status and time-correlated data in multiple formats for viewing simultaneously.

Currently there are two measurement modules available, called Pyramid and Magnifying Glass. Pyramid is a general-purpose module for examining detailed operation of the most sophisticated microprocessors, including 88000, R3000, 29000 and Sparc devices. Magnifying Glass, when used in conjunction with Pyramid, allows you to examine part of a trace in detail; it is capable of sampling at 1GHz.

An instrument with a price of under £1000 brings 100MHz logic analysis within the reach of small companies and educational establishments.



With its tried and tested human interface in the form of a Mac, Gould's CLAS4000 is easy to control, even though it is a highly complex analyser.

Don't get fooled by specifications

Marconi Instruments says that many logic analyser manufacturers cook the figures by creating confusion between sampling and decision rate. The company points out that the two may not necessarily be identical.

Naturally enough it uses its latest offering, the 50MHz 5500 logic analyser, as the ideal example of how these instruments should be specified.

The essence of the confusion is this. Unless an analyser can evaluate a logic condition and then store a particular event within the time span between two successive samples, then its effective working speed must be less than the sampling rate.

Its own instrument is claimed always to evaluate a logic expression within the 20ns span between the 50MHz samples. It is also said to detect and place a marker on logic glitches down to 4ns.

Marconi says a further source of error frequently arises through circuit loading. Its 5500 instrument overcomes this by using up to 240 high impedance probes, each with a bandwidth of 100MHz and an associated capacitance of just 5pF.

Marconi's instrument has been designed for testing large microprocessor systems including the latest issue of Intel and risc parts. Prices start at £10 500 for a basic 48-probe machine expandable in multiples of 48.

UPDATE

Research profile – Cranfield

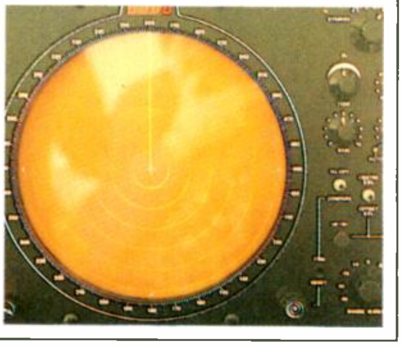
MARTIN ECCLES

Cranfield Institute of Technology is a very business-like university. It probably has the closest links with industry of any university and it claims to be the largest academic centre for industrial research, development and design in western Europe. Cranfield also researches for defence – the Royal Military College of Science became a faculty of Cranfield in 1984 – and the public services.

Being applications-oriented, and working so closely with industry, Cranfield is quite well off. A number of offshoot companies have evolved from research projects, providing anything from consultancy and troubleshooting services to products like data loggers for racing cars.

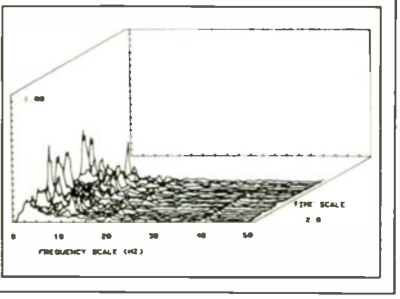
In radar displays for air-traffic control, clutter reduction using FFT does not provide a perfect solution. Analysis and reduction of clutter in radar returns is currently the subject of research in Cranfield's Department of Electronic System Design.

Theoretical studies of clutter using spectral and statistical analysis techniques have made possible the construction of computer models. These computer models can simulate natural and man-made clutter which can then be used to assess the efficiency of various clutter-reduction techniques.



Clutter-reduction methods involve both spectral and statistical techniques to distinguish between the target and clutter. Many of the models are running on a Vax cluster together with several PDP11/83 minicomputers fitted with DSP coprocessors.

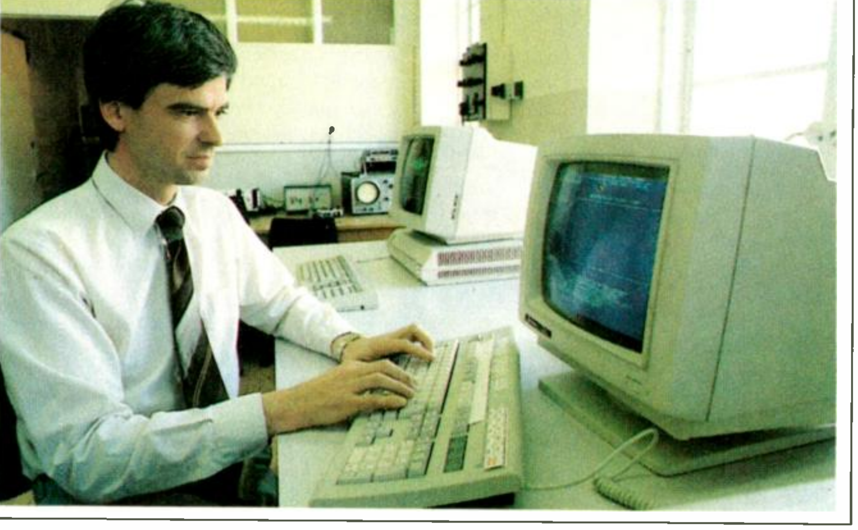
Some research is needed into exposure times for photographing radar screens like the one shown here. Had the predicted four seconds been enough, I would have been able to show you before and after shots illustrating how statistical and spectral processing removes clutter.

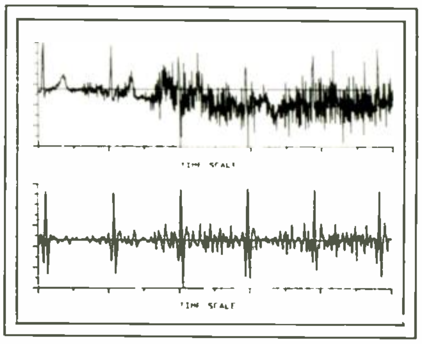


One of the most interesting finds in Doug Russell's brain-interface work (above, centre) is the tiny 40Hz ripple on this brain-wave graph that you can see disappearing towards the back of this three-dimensional plot.

This plot is an EEG spectrum obtained from a subject looking at a visual stimulus of 40Hz for about the first two-thirds of the experiment, which is devised to investigate the eye/brain pathways. Doug Russell is also looking at brain wave patterns to try and detect whether pilots have fallen asleep.

Judging by all the publicity a few years ago, you would think that speech recognition would be more in evidence by now: could there be problems? Researcher Doug Russell is bypassing speech recognition and instead looking into the possibility of interfacing computers directly to the human brain. This work is part of a wide-ranging research project into reducing pilot stress.





One of the best ways of looking at stress in pilots is to monitor the electrical signals that control the heart beat. While the pilot is not moving the signals are easy to measure but as soon as any movement is made, the signals going to the large muscles in the upper body swamp those detected from the heart.

As you see here, signal processing, in the form of high-speed adaptive filtering, removes noise from the ECG.

Dominant activities of Cranfield's microprocessor application group are now software engineering and microelectronics in which expertise in real-time systems is most significant.

This display is of a prototype simulator using transputers. The simulator faithfully represents the dynamic characteristics of a weapon system, its missiles and many independent moving targets, including high speed aircraft. Normally, the display includes a realistic background terrain image.

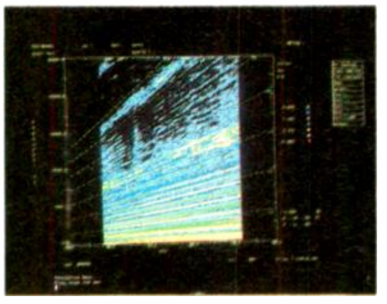
Such simulators must be flexible, reconfigurable and require the most efficient combination of hardware and software. These systems have only become cost-effective with the advent of modern devices.

UPDATE

Dynamic analysis of rotating machinery such as aero engines, power generation plant, automotive engines, etc., both in the development stages and as a part of routine maintenance programmes, enables engineers to optimize design and to programme planned maintenance shut downs when necessary.

Analysis of this type is usually performed during a speed run-up or run-down of the machine. Often the acceleration and deceleration rates can be quite rapid, creating a need for collection and analysis of vast amounts of data in very short time frames.

The illustration shows a display from EDASP 9000 of an acceleration of a jet engine displayed as a composite Campbell diagram. In essence, the colour-coded amplitude display shows, in three-dimensional form, the areas of high vibration amplitude, with corresponding frequency and speed information. Armed with this information, the engineer can ask the computer to perform order and frequency tracking to examine the behaviour of harmonic orders or frequencies as a function of speed.

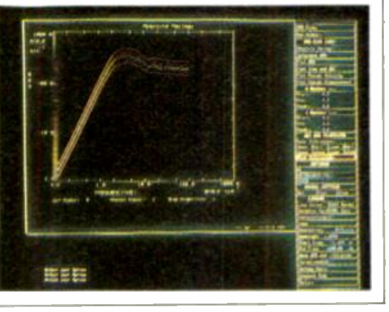


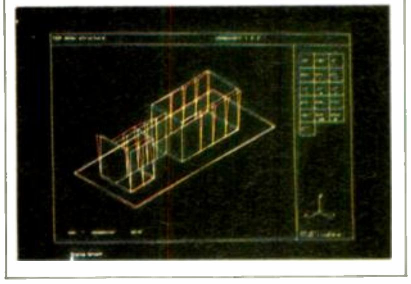
One company within the Institute is devoted to research into precision mechanical engineering. This company, CPE, has produced a machine-tool guidance system consisting of modules for everything from bed positioning to user interfacing.

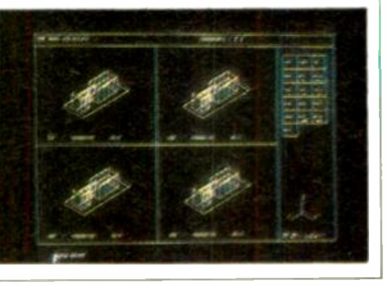
Cuproc, as the system is called, is for producing complex profiles with high precision on a multi-axis machine tool. Tool-path accuracy is ensured by unique high-resolution feed-forward techniques and laser interferometry. Cuproc's curve-fitting software is capable of a resolution of 1.25nm at a speed of 0.9m/s.

In aerospace and defence industries, electronic and mechanical systems often have to operate in severe shock environments. Also, almost every commercially purchased product has to be protected by packaging enabling it to withstand the shock and vibration experienced during transport from the factory to the end user. Shock testing of products or packaging is generally carried out by using drop-test methods; however, other techniques such as using electrodynamic shakers, hydraulic or pyrotechnic techniques are also in common use.

Systems such as Cranfield Data Systems' EDASP 9000 rapidly perform complex shock analysis, such as the shock response spectrum illustrated, on vast amounts of data.

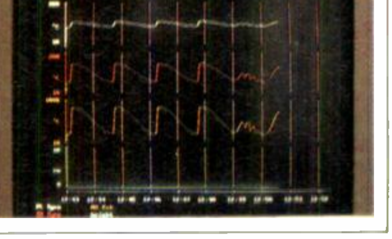






Modal analysis plays an important role in the understanding of the dynamic behaviour of structures. Advanced signal processing systems such as the Cranfield Data Systems EDASP 9000 series carry out comprehensive analysis in a fraction of the time that it would have taken a few years ago. Structures tested can be as small as a few inches or as large as an aircraft. Response measurements are taken from multiple points, often hundreds, on the structure. The system performs transfer function analysis and curve-fitting routines and provides the engineer with an animated display of the modal behaviour of the structure, combined with measurements such as the damping values for each mode.

The structure shown on the displays here is an aluminium housing from an aerospace application which is designed to contain delicate printed-circuit assemblies. Modal analysis enables engineers to establish the suitability of a design for use in the environment in which it will operate.



Real-time telemetry is used to monitor racing-car performance. Cranfield's Microsystems Design Group has developed a telemetry link in the form of a UHF transmitter that sends data from sensors within the car to a PC.

With such a system, the race manager in the pits can request updates on parameters such as oil and water temperatures, ride height and fuel consumption. It is even possible to detect a slowly leaking tyre.

Software for producing the telemetry display shown here is part of the system.

Read-write optical disc for DEC, PC and Sun

Magneto-optical technology in a 640Mbyte drive allows as much reading and writing as you like without the chance of accidental erasure through magnetic fields.

MARTIN ECCLES

A random-access storage capacity of over 600Mbyte on one 5¼in disc is in itself quite useful, but combine that with the portability of a floppy disc, the speed of a Winchester and the data safety of a compact disc and you have a very interesting storage medium. On top of that, non-contact head also remove the possibility of crashes – one of the primary data-loss culprits.

Decade Computers of Newbury is now distributing the Alphatronix Inc. erasable optical storage system in the UK. Inspire, as the system is called, connects to Sun 2/3/4 workstations and PC, XT and AT compatibles. It is also the first optical read/write system for DEC workstations, specifically PDP, MicroVax and Vax machines.

Read/write optical discs are not just an alternative to existing storage media. They suit applications where there is too much data for floppy discs, where hard-disc storage is too costly and where tape storage is too slow. Such applications include cad/cam, image and data processing and desktop publishing. Since the disc is in cartridge form, data is easily archived and the need for tape back up is removed.

In medical imaging for example, a chest X-ray needs about 30Mbyte of storage capacity; where tomography, nuclear magnetic resonance and X-ray scanning techniques are used there can be dozens of these images for one patient. Magneto-optical storage, in conjunction with a medical workstation, simplifies and cheapens image enhancement and allows convenient archiving.

Currently, the drives cost from about £6000; a disc costs around $300 but when production rises, that price is expected to fall to between $25 and $50. Compared with $1200 for two removable 300Mbyte Winchester disc packs or $600 for the equivalent floppy disc capacity, $300 is cheap. In fact, it works out at about the same price as half-inch magnetic tape.

One of the main worries with having so much valuable data on one disc is that the manufacturer will go out of business. There is already a standard for 5¼in optical drives agreed by ISO, ECMA, ANSI and Japan's MITI Committee 23. Inspire conforms to this standard (ISO DP10089-1) and there are already two sources of discs – 3M and Sony.

It is too early yet to say what will happen in the optical storage field. If a manufacturer comes up with an extremely cheap non-standard system, drives conforming to the standard could suddenly become prohibitively expensive. The chances are though that the byte-for-byte prices are even now so competitive that potential users of such a system will not be able to afford to wait around to see what will happen.

OPTICAL READ/WRITE TECHNOLOGY

There is more than one optical read/write technology, but the magneto-optical method used in Alphatronix's Inspire is proving to be one of the most popular.

Conventional magnetic media rely on using as small a magnetic field as possible, so it is not surprising that they are easily erased by loudspeakers and TVs. Magneto-optical discs, on the other hand, can only be erased by very high magnetic fields. Dr Robert Freese, President of Alphatronix, claims that it would take a room-sized electromagnet of the type used in research to erase a magneto-optical disc; placing an ordinary magnet on the surface of the disc has no effect.

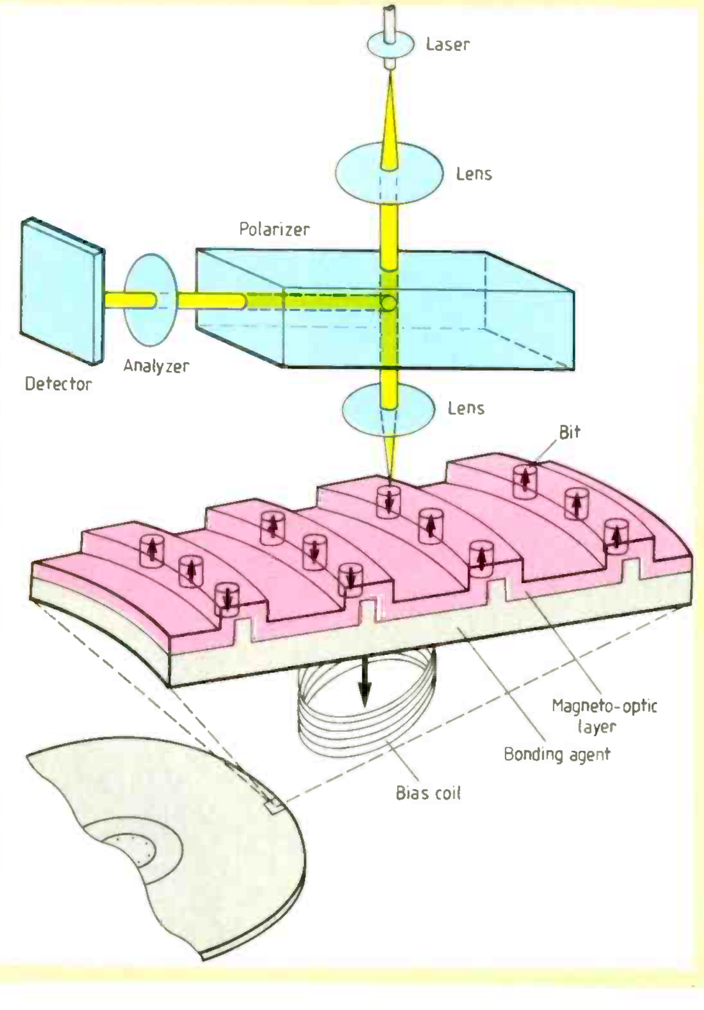
The magnetic material is in the form of a thin film on the disc's surface and is vertically magnetized north-pole up for a logical one and south-pole up for a logical zero. A transparent plastic film covers the magnetic surface. At normal temperatures, the coercive force needed to flip a domain is in the region of 400kA/m but at about 150°C that force falls to almost zero.

During writing, a semiconductor laser of about 8mW output heats the domain making it possible for a bias coil creating a small magnetic field to flip the domain's polarity.

A pulse of a few nanoseconds from an infrared laser heats a bit domain 1μm across to a temperature that allows the bias coil to determine the polarity of the magnetic particle representing the bit's state.

Reading of a domain is carried out by the same beam but at a reduced power. After reflection off the disc surface, the read beam's polarization varies depending on the polarity of the domain under it (Kerr magnetic-optical effect), hence ones and zeros can be differentiated.

Optical read/write technology is still in its early days. Predictions based on envisaged advances in optical heads, more efficient recording and error-correction methods and the use of visible-wavelength laser diodes now under development indicate that the current 5¼ in disc capacity could be increased to 7000Mbyte and the existing data transfer rates could go from 5Mbit/s to 500Mbit/s.



RF EQUIPMENT

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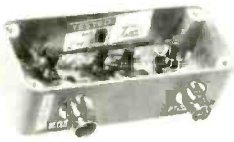
TYPE 9006FM. As above. Band II 88-108MHz £78
TYPE 9002. Two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Tuned to your specified channels in bands IV or V £102
TYPE 9004. UHF two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Aligned to your specified frequency in the range 250-1000MHz £102
TYPE 9035. Mains power supply for above amplifiers £30
TYPE 9010. Masthead weatherproof unit for above amplifiers £12



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TYPE 9002

WIDEBAND AMPLIFIERS

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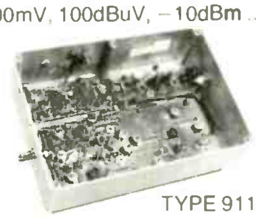
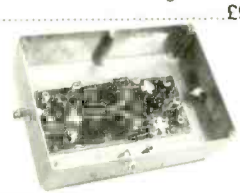
TYPE 9253. 40-860MHz. NF 6dB. Gain 30dB. Voltage output 100mV, 100dBuV, −10dBm £94



TYPE 9113



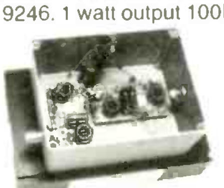
TYPE 9252

PHASE LOCKED LOOP FREQUENCY CONVERTERS

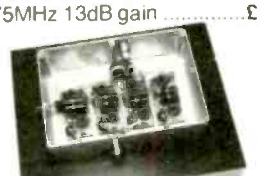
TYPE 9113 Transmitting. Converts your specified input channels in the range 20-1000MHz to your specified output channels in the range 20-1000MHz. 1mV input, 10mW output (+10dBm). AGC controlled. Gain 60dB adjustable −30dB. Will drive transmitting amplifiers directly £356
TYPE 9114 Receiving. Low noise Gasfet front-end. NF 0.7dB. Gain 25 dB variable £356

TMOS WIDEBAND LINEAR POWER AMPLIFIERS

TYPE 9246. 1 watt output 100KHz-175MHz 13dB gain £108



TYPE 9176



TYPE 9271

TYPE 9247. 4 watts output 1-50MHz 13dB gain £108
TYPE 9051. 4 watts output 20-200MHz 13dB gain £108
TYPE 9176. 4 watts output 1-50MHz 26dB gain £254
TYPE 9177. 4 watts output 20-200MHz 26dB gain £254
TYPE 9173. 20 watts output 1-50MHz 10dB gain £308
TYPE 9174. 20 watts output 20-200MHz 10dB gain £308
TYPE 9271. 40 watts output 1-50MHz 10dB gain £616
TYPE 9172. 40 watts output 20-200MHz 10dB gain £616
TYPE 9235. Mains power supply unit for above amplifiers £164

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Very high stability phase-locked oscillators operating directly on the signal frequency using a low frequency reference crystal. Phase noise is typically equal to or better than synthesized signal generators. Output will drive the Types 9247 and 9051 wideband linear power amplifiers and the Types 9252 and 9105 tuned power amplifiers.

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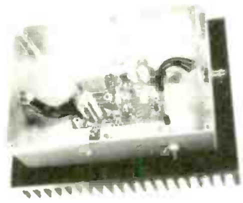
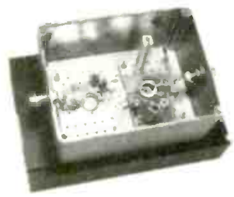
TYPE 9087. Includes integral mains power supply £1,110
TYPE 9182FM exciter ±75KHz deviation. Output 10mW £248



TYPE 9263



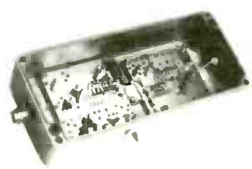
TYPE 9259

TELEVISION LINEAR POWER AMPLIFIERS

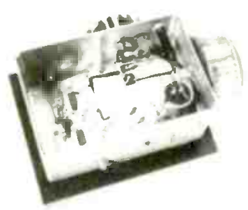
Tuned to your specified channels in bands IV or V. 24V + DC supply.

TYPE 9261. 100mV input, 10mW output £218
TYPE 9252. 10mW input, 500mW output £254
TYPE 9259. 500mW input, 3 watts output £290
TYPE 9262 500mW input, 10 watts output £530
TYPE 9263. 2-3 watts input, 15 watts output £400
TYPE 9266 10 watts input, 50 watts output £1,585

See below for Television Amplifiers in bands I & III.



TYPE 9105



TYPE 9158/9235

TMOS RF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range 20-250MHz, or your specified channels in bands I or III. 24V +DC supply.

TYPE 9105. 10mW input, 1 watt output £230
TYPE 9106 500mW input, 10 watts output £284
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ENTER 14 ON REPLY CARD

Alpha-torque forces

Neglect of basic physics, argues the author, has led us to overlook some extraordinary electrical phenomena. He envisages uses ranging from party tricks to industrial and military applications, including a space catapult of astonishing power.

PETER GRANEAU

Nearly 170 years have elapsed since Oersted discovered electromagnetism. The dominant theory of the first 80 years was the electrodynamics (interaction of current elements) developed by Ampere in France and Neumann in Germany. It presided over the inventions of electricity generators, motors, transformers, transmission lines and electromagnets. The whole of electric power engineering can be explained with it. Flourishing in the schools of France and Germany, the key memoirs were not translated into English. Contemporary scientists and engineers are largely ignorant of the old electrodynamics and frequently confuse it with later ideas. As Newton did with universal gravitation, and Coulomb with electrostatics, Ampère based his fundamental force law – which Maxwell later called the cardinal formula of electrodynamics – on simultaneous far-actions, or instantaneous action-at-a-distance. The resulting Ampère-Neumann electrodynamics is a theory which was specifically developed for the flow of electric currents in metallic conductors[1].

Electron beams in a vacuum do not obey Ampere's force law. This caused Lorentz to develop an alternative electrodynamics[2] which he based on the Lorentz force formula. It became the electrodynamics of Einstein's Special Theory of Relativity. It openly violates Newton's third Law of equal and opposite reaction forces between particles of matter. For certain metallic conductor arrangements, both the old Newtonian and the modern relativistic electrodynamics predict identically the same ponderomotive forces which agree with measurements. However, there are important exceptions to this rule which escaped Lorentz's attention. They fall into four groups: (1) electrodynamic jets at solid/liquid interfaces; (2) tensile wire fragmentation; (3) linear momentum conservation; and (4) electric arc expansion. Experiments in all four groups support Ampere's law and contradict Lorentz's. Fifteen of the experimental tests favouring the old electrodynamics have been fully reviewed in reference 1.

In view of this, the unification of the Coulomb law of electrostatics with the force law of electrodynamics, attained in the Lorentz force formula, now appears to be null and void, at least as far as metallic conductors are concerned. While *avant-garde* physics storms ahead with supercolliders and the unification of *the* electromagnetic force with nuclear forces, we find that simple bench-top experiments have been de-unifying electric and magnetic actions. Alpha-torque forces will play an important role in this evolving drama.

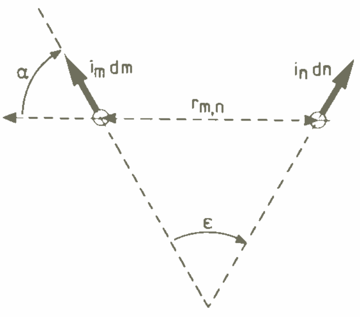


Fig.1. Angular degrees of freedom of two Ampèrian current elements.

The old electrodynamics is by no means a complete theory. In a recent enlargement of it[1] it has been shown why two Amperian current elements, which differ from Lorentzian current elements in substantial details, must be subject to mutual torques or turning moments. The torques are superimposed on the mutual forces of attraction or repulsion existing between the current elements. An interacting pair of Amperian current elements, $i_m dm$ and $i_n dn$ has two angular degrees of freedom. The two angles are shown in **Fig.1** and have been denoted by the Greek letters alpha and epsilon. Each of the angles is associated with a mutual torque. The alpha-torque is ponderomotive in nature and acts on the atoms of the conductor metal, *and not on the conduction electrons*. It has many technological ramifications.

DERIVATION OF THE ALPHA-TORQUE FORCE

Neumann was responsible for introducing the concept of the electrodynamic potential P. This is measured in joules and in modern physics it is called stored magnetic energy. Neumann was also the originator of the virtual work concept. This states that if the stored magnetic energy between two current circuits changes with the distance between the circuits, then there must exist a force between the circuits. Similarly, if the stored energy changes when one of the circuits is rotating with respect to the other, then there must exist a mutual torque between the circuits.

In the recent extension of the old electrodynamics[1] it has been shown that the stored magnetic energy $\Delta P_{m,n}$ between two Ampèrian current elements $i_m dm$ and $i_n dn$ is given by

$$\Delta P_{m,n} = -(\mu_0/4\pi) i_m i_n (dm.dn/r_{m,n}) [(0.5\cos\varepsilon) - 1.5\cos(2\alpha+\varepsilon)] \quad (1)$$

where $r_{m,n}$ is the distance between the elements and the angles α and ε are indicated in Fig.1. Ampère[3] proved that any three-dimensional current element problem reduces to a two-dimensional problem because the out-of-plane forces and torques are zero. This is the justification of the universal representation of Amperian current elements by diagrams like Fig.1.

The principle of virtual work[4] requires the mutual force $\Delta F_{m,n}$ between the element pair to be

$$\Delta F_{m,n} = -(\partial/\partial r_{m,n}) \Delta P_{m,n} = -(\mu_0/4\pi) i_m i_n (dm.dn/r^2_{m,n}) [(0.5\cos\varepsilon) - 1.5\cos(2\alpha+\varepsilon)] \quad (2)$$

This equation is Ampere's force law which he proposed in 1822. By the same virtual work principle, the mutual alpha-torque between the two current elements $(\Delta T_{m,n})_\alpha$ turns out to be

$$(\Delta T_{m,n})_\alpha = -(\partial/\partial\alpha)\Delta P_{m,n} = -3(\mu_0/4\pi) i_m i_n (dm.dn/r_{m,n}) \sin(2\alpha+\varepsilon) \quad (3)$$

INDUSTRIAL, MILITARY AND SPACE APPLICATIONS

Potential industrial applications of alpha-torque phenomena range from the suppression of turbulence in aluminium smelters and other metal processing cells; the control of metal flow in arc furnaces and in arc welding; liquid metal pumping and stirring; metal forming and cutting with water projectiles; pressure welding of dissimilar metals by water impact; rock blasting and other mining operations; the control of switching arcs in air, gases and vacuum; current limiting fuses; and so on.

The more important military applications of Ampère forces are likely to be related to the water-arc launcher and the sea-water jet. The water-arc gun appears to be ideal as an anti-tank weapon and also as a kinetic energy killer of ballistic missiles. The sea-water jet could become a powerful torpedo drive or a silent propulsion device for submarines.

Space launching of small payloads with the water-arc launcher is a particularly exciting prospect.

The alpha-torque force is the torque of equation 3 divided by the torque arm $r_{m,n}$, that is

$$(\Delta F_{m,n})_\alpha = 3(\mu_0/4\pi)(dm.dn/r^2_{m,n}) \sin(2\alpha+\varepsilon)$$

To obtain an idea of the relative magnitudes of the various Ampere forces, we shall compare them for the normalized case of $i_m = i_n = 1A$, and $dm = dn = r_{m,n} = 1mm$. The negative sign in equation 2 stands for attraction. When the force becomes positive it changes to repulsion. Maximum repulsion occurs between elements lying on the same straight line, as indicated in **Fig.2a**. It is equal to 1×10^{-7} N. When the elements are arranged side by side **(Fig.2b)**, they exhibit a maximum attraction of 2×10^{-7} N. The

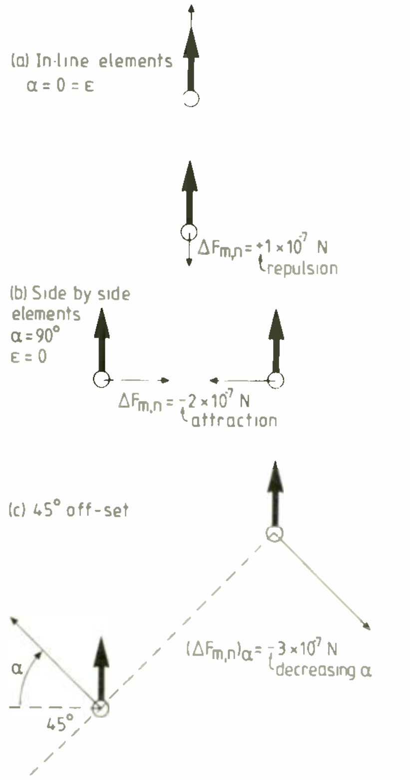


Fig.2. Principal Ampère forces between a pair of current elements.

greatest alpha-torque force occurs when the elements are offset by 45° as in **Fig.2c**. The maximum alpha-torque force is found to be 3×10^{-7} N, acting in such a direction as to decrease the angle α. In general, therefore, the alpha-torque forces are stronger than the attractions and repulsions between Amperian current elements.

LIQUID METAL CELLS

Whilst most of the important inventions made in the past few centuries were far ahead of explanatory science, we are now in a phase in the history of science when we expect innovation to arise from modern physics theory. When this theory is at variance with experience, as the relativistic electrodynamics is, we are in danger of missing out on possible important technological advances. Consider the liquid metal cell of **Fig.3**. This may be taken as a model of several industrial metal processing plants in which large direct currents are passed from a solid anode to a solid cathode via a liquid metal bath. Examples are aluminium smelters and other metal reduction cells.

If the Lorentz force were the ruling electrodynamic law, the only electrodynamic forces experienced by the atoms of the liquid metal pool would be pinch forces of the type shown in Fig.2b. These forces are also predicted by Ampere's law. The direction and distribution of the pinch forces in the liquid metal pool is such that they create hydrostatic pressure but cannot produce liquid metal circulation.

Contrary to this expectation, an experimental test with liquid mercury[5] did reveal liquid metal circulation, as indicated in Fig.3. This observation agreed with the existence of the two types of Ampere forces depicted by Fig.2a,2c, which are not included in the relativistic electro dynamics taught at present. The alpha-torque forces between current elements in the liquid metal pool push atoms radially outward in and near the centre plane between anode and cathode. This action is reinforced by Ampere repulsions between solid elements in the electrodes and liquid elements in the pool.

The metal circulation in the cell provides free stirring, if the process should require it. When no stirring is needed, as in the reduction of aluminium, circulation has the disadvantage of wasting energy and eroding the electrode surfaces. Hall-Heroult aluminium reduction cells are known to be only 35 percent energy efficient. Much of the wasted energy is converted to Joule heat. But 15 percent could be spent on harmful metal circulation. If true, this would amount to 24×10^9kWh of electricity per year in the US alone. This waste of energy somehow remains hidden if we choose to ignore the alpha-torque forces of the Ampere electrodynamics.

THE LIQUID MERCURY FOUNTAIN

An even more dramatic result of the existence of Ampere forces is the liquid mercury fountain **(Fig.4)**. This was achieved in my MIT laboratory with liquid mercury contained in the dielectric cup. An insulated copper rod electrode, bare on the end face, projected through the bottom of the cup. A copper ring electrode was partially submerged in the free top surface of the mercury. The cup was 4.5cm deep and 6.4cm in diameter. With 500 to 1000A flowing between the electrodes, a conical fountain head would form above the free surface of the liquid metal (Fig.4b). Mercury could be seen to stream down the cone. While the current was maintained, the mercury flow and circulation was continuous. This behaviour proved that the electrodynamic force system propelling the fountain did not prevent liquid mercury from streaming back laterally toward the rod electrode, deep inside the cup.

The broken lines in Fig.4a from the rod to the ring electrode represent current streamlines in the mercury. The Lorentz forces must act transversely to these lines, and radially inward near the rod electrode. This relativistic action produces only pinch on the mercury column above the rod electrode. By hydrostatic action, this pinch would be converted to an upthrust *as well as* a downthrust. The downthrust would prevent liquid atoms from entering the column to replenish others which have been transported into the fountain head. Hence present electrodynamics does not permit liquid mercury circulation and is therefore incapable of explaining the observed jet fountain.

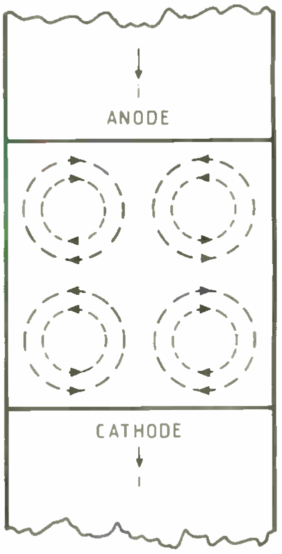
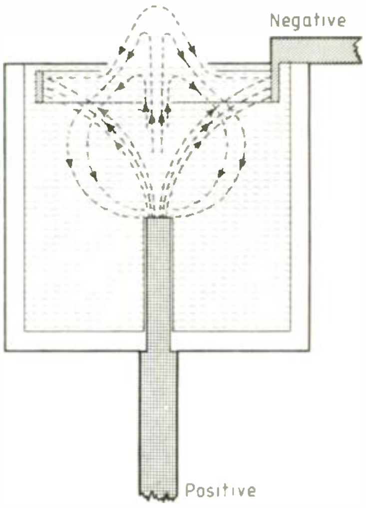


Fig.3. Circulation in liquid metal cell.



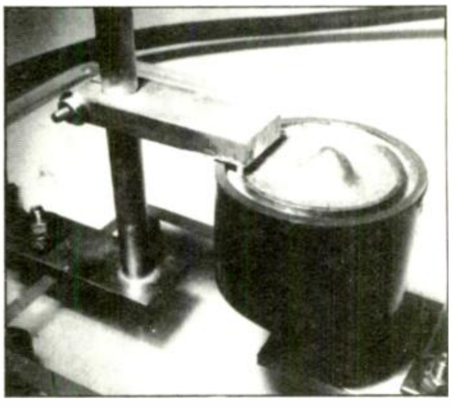


Fig.4. Above, cross-section through mercury fountain and (lower) photograph of it.

In 1982 this experiment was demonstrated before an audience of professors, researchers, and graduate students of the

Massachusetts Institute of Technology. Some of the distinguished MIT professors refused to look at the mercury fountain, lest it might upset their routine lectures on electromagnetism. Their behaviour reminded me of the professorial colleagues of Galileo who refused to look through his telescope to observe the moons orbiting around Jupiter.

Applying the Newtonian Ampere electrodynamics to the liquid mercury fountain, we find that repulsions and alpha-torque forces assist each other in causing the upflow of liquid mercury. By action-at-a-distance, the forces of reaction to the lift forces then reside in the solid rod and in the ring electrodes. In this way the reaction forces are not creating back-pressure in the liquid which would stop it from circulating. The operation of the liquid mercury fountain was completely silent.

SEA-WATER JET

It seems feasible that the principle of the liquid mercury fountain can be exploited to design a sea-water jet engine, as an alternative to the propeller[6] **(Fig.5.)** Research on MHD ship propulsion has been in progress in Japan for the past ten years[7]. The Japanese technique is based on the use of Lorentz forces which arise in a magnetic field in sea-water when direct current is driven through the water and across the magnetic field lines. A superconducting magnet on board ship is being employed for generating the strong magnetic field. Only a small current can be made to flow through salt water because of its high resistivity.

Published results indicate that a 700kg magnet-cryostat combination in a small wooden vessel was able to drive vessel at a velocity of 0.6m/s. A current through the water of 65A produced a thrust of 15N. The sea-water jet of Fig.5 is expected to be a far more effective means, per kilogram of power supply, for driving surface and submarine vessels or torpedos.

Like the liquid mercury fountain, the sea-water jet also contains rod-and-ring electrodes. For the operation of the sea-water jet, a sufficiently high voltage must be maintained between the electrodes to form a continuous electric arc in the water. The water arc has a very low resistivity and, therefore, allows the flow of large currents. The arc plasma is the most important component of the jet engine. It takes the place of the liquid mercury in the fountain. Most of the ship propulsion force is the reaction force on the copper atoms in the rod electrode. A component of the reaction force in the ring electrode is also expected to contribute to propulsion. This latter component arises from alpha-torque forces.

Will the sea-water jet be noisy or silent? Silent drives are known to be of great interest to the navy. Jets will not generate the rotary turbulence characteristics of propellers. However, when first switched on, and if no special precautions are taken, the establishment of the arc will be an explosive event. Subsequently the drive might well be as silent as the liquid mercury fountain. The electrodynamic propulsion force is proportional to the square of the current.

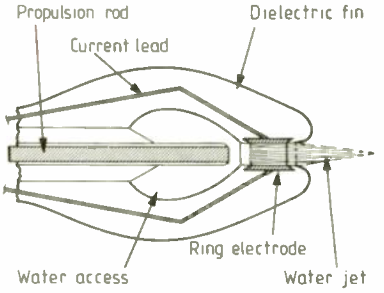


Fig.5. Sea-water jet.

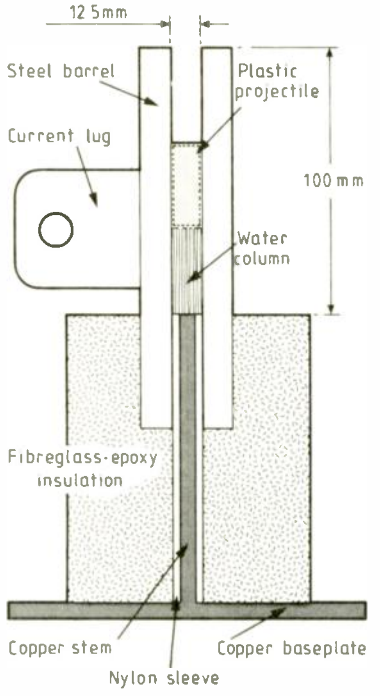


Fig.6. Miniature coaxial water-arc gun.

Therefore the constancy of the current is likely to decide how noisy or silent a drive it will be. Continuous arcs in air burning between carbon electrodes are hissing. This is the result of small fluctuations in the air ionization process. The continuous ionization of salt water is expected to be a much smoother process because of the presence of sodium and chloride seed ions. How silent a drive the sea-water jet can be made will have to be decided by experiment.

WATER-ARC LAUNCHERS

Ampere designed his electrodynamic force law to explain the behaviour of metallic conductors. The law failed when it was applied to electron beams in vacuum. How does it fare with plasma conductors? At the end of the 1980s we have amassed enough experimental evidence to feel confident that Ampere-Neumann electrodynamics does hold for high-density plasmas such as those found in lightning channels and underwater electric arcs. There is no way of telling, as yet, how far the plasma density must fall before Ampere's force law breaks down.

Water-arc explosions caused by short current pulses have in recent years become a most fascinating research topic. In 1947 Frungel[8] experimented with the first water-arc launcher. He had a rod-and-ring electrode arrangement in which the ring, sealed to a dielectric plate and covered by a mica sheet, formed the pressure vessel. Water filled the annular cavity between the electrodes. By discharging a 12.2kV, 0.07μF capacitor through the water, Frungel was able to catapult a two-gram weight, lying on the mica sheet, two metres up in the air. The energy stored in the capacitor was only 5.2J. The projectile travelled with an initial velocity of 6.26m/s. The mica sheet, on which the projectile rested, stayed in place, demonstrating that the weight was accelerated by a sharp blow probably lasting no longer than the 50μs current pulse. All the water remained under the mica sheet and there was no residual steam pressure present capable of lifting the sheet after the projectile had departed.

The energy supplied by the capacitor was insufficient to raise all the water to 100°C and convert it to steam. Those not familiar with the science of dielectric breakdown usually argue that the arc energy may have been concentrated in a tiny steam bubble which would then create an arbitrarily large pressure. The fact is there exists no breakdown mechanism which could confine the discharge of thousands of amperes to a small volume of the electric field between the electrodes. Quite the contrary is the case. Photography proves that all of the interelectrode gap is fully aglow with plasma **(Fig.7)**. From these facts we know the water-arc explosions are not driven by thermal action. Frungel then considered Lorentz forces, but came to the conclusion that they would try to contain the arc plasma rather than explode it. Not having any knowledge of the Ampere electrodynamics, he reluctantly concluded: "A satisfactory explanation of this phenomenon (water-arc explosion) could not be found". It is now over 40 years later and we finally are making some progress by applying the Newtonian electrodynamics to the problem.

The most powerful water-arc launcher which has so far been built is shown in **Fig.6.** It is still only a miniature device with a 10cm-long gun barrel. Being subjected to a 75kA current pulse, this miniature gun produced an acceleration force of no less than 31 640N. It ejected a 3.8g coherent slug of salt water from the barrel at an estimated velocity of 1000m/s. After flying 10cm through the air, the water crashed through a quarter-inch thick aluminium plate and then was captured on the other side of the plate. The captured water was found to be lukewarm and still contained all the salt in solution.

Electrodynamic propulsion mechanisms are expected to attain higher projectile velocities than gas expansion accelerators. The limitations of adiabatic gas expansion have prevented chemical guns from shooting objects into space. Electrodynamic water-arc launchers are a potential alternative to rocket launchers for unmanned space missions in which the payload can withstand the high accelaration of a gun launch.

On the basis of experimental results obtained with small water-arc launchers, it now seems feasible to accelerate a 20kg mass to 14km/s (well above Earth escape velocity) in a multi-stage water-arc barrel of less than 100m in length. The barrel could be installed in a one-foot diameter vertical borehole drilled through bedrock. About 3GJ of energy would have to be made available from an electromagnetic energy store. A space launcher of this kind should be capable of placing the plutonium charge of a single nuclear warhead into a suitable solar orbit, as for example the Asteroid belt.

THUNDER

The cause of thunder is one of the oldest riddles of recorded scientific speculation. Three centuries BC, Aristotle published the first thunder theory. Many others were proposed until at the beginning of the present century a consensus evolved which assumed thunder must begin with a shock-wave in air due to the sudden thermal expansion of the plasma in the lighting channel. The only experimental support for this theory came from spectroscopic temperature determinations up to 36 000K. Any one of a number of assumptions made in equating "optical" to thermodynamic temperatures can be challenged and some have been outright disputed.

Experiments with short atmospheric arcs of lightning strength revealed average arc pressures in excess of 400 atmospheres and peak pressures approaching 1000 atmospheres. These results demand much higher temperatures than those found by lightning spectroscopy. Furthermore, when the strength of the laboratory arc explosions was plotted against the integral of the current pulse, it followed an electrodynamic law rather than a heating curve. Arc photography then proved conclusively that the plasma did not expand thermally in all directions, but preferentially at right angles to the current, as if driven by organized electrodynamic action, and in particular alpha-torque forces.

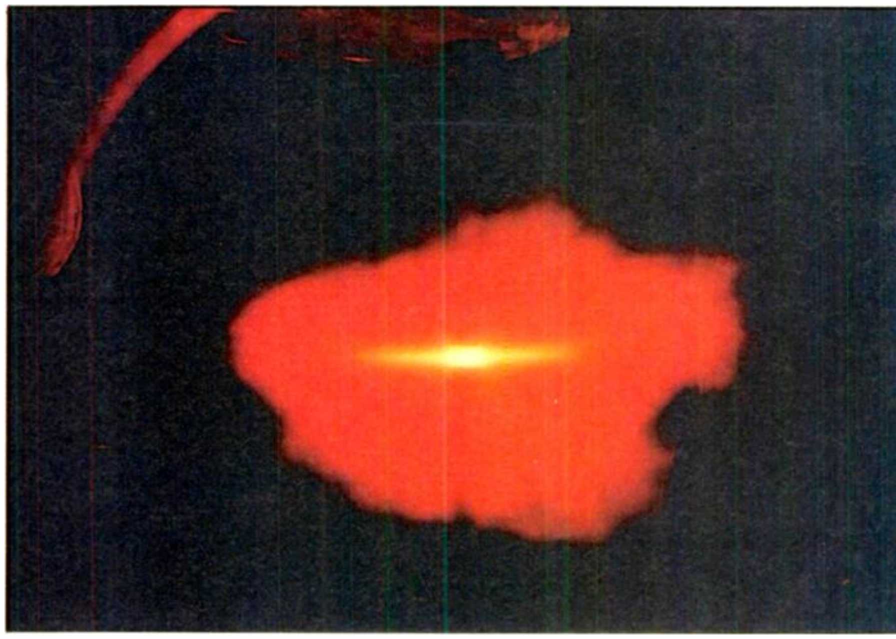


Fig.7. Atmospheric arc expansion.

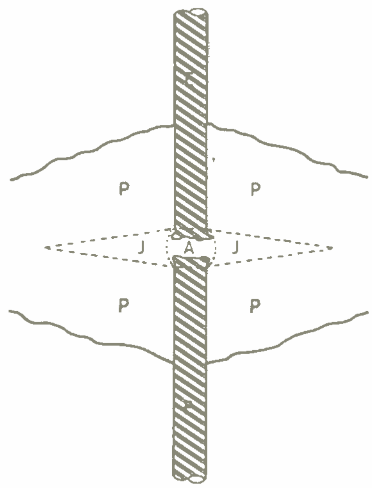


Fig.8. Explanation of the atmospheric arc photograph of Fig.7.

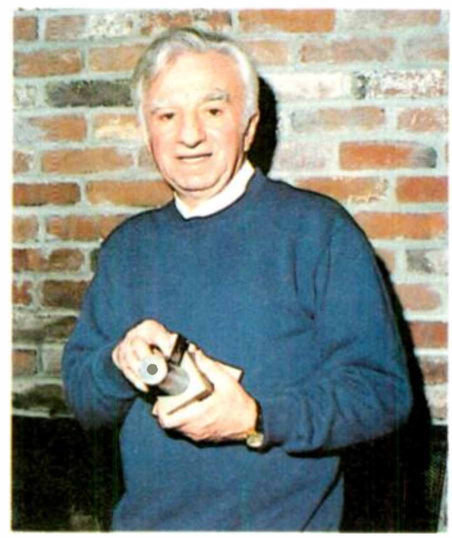


Fig.9. Author with miniature water-arc gun.

Figure 7 is an open-shutter photograph of a 45kA, 188μs arc in atmospheric air between quarter-inch diameter stainless steel rod electrodes. It was taken at a distance of 30cm from the arc with a 12cm stack of filters placed in front of the camera. **Figure 8** has been drawn to explain the features of the colour photograph which furnished the most direct evidence of alpha-torque forces in action.

The arc region in which ions and free electrons are created and accelerated toward the metal electrodes E (Fig.8) is denoted by A. The strong electric field is confined to the arc region. Surface melting ocurred where the arc was rooted on the metal electrodes and where most of the ion recombination heat must have been liberated. After ten shots, outward flow of molten metal had made the electrode ends dome-shaped, and pronounced lips had formed at the edges. The arc enveloped the lips and thereby concealed their outline on the photograph. Bright amber jets J can be seen to emerge from the bright amber arc region A. The jet focused on an edge which, when photographed from above, was found to be a circle. In three dimensions the J-region had the shape of a discus. A sharp boundary can be seen to separate the J-region from the surrounding red "plume" P. In successive shots, utilizing the same current pulse, the J-region was always the same shape and size. However, the outline of the plume varied from one shot to the next, presumably on account of air draughts. The outline of the J-region appears to be the shock front at the time the light emission became faint. The wedge-shaped plasma stream confirms the radial ejection of ions from the arc, exactly as predicted by the alpha-torque forces. The shockfront is certainly not of the spherical shape that would be produced by omni-directional thermal plasma expansion. All along the shock front, ion pairs appear to have been scattered into the ambient air. These ions become entrained in the surrounding air. This explains the existence of the red plume. Photographs like Fig.7 have furnished decisive evidence against thermal arc expansion. From them one may reasonably conclude that thunder is not caused by heat in the lightning channel, but rather by radially outward directed alpha-torque forces. ■

References

1. P. Graneau, Ampere-Neumann electrodynamics of metals, Hadronic Press, Nonantum MA 02195, USA, 1985.

2. H.A. Lorentz, The theory of electrons, Teubner, Leipzig, 1909.

3. A.M. Ampere, Theorie mathematique des phenomenes electro-dynamiques uniquement deduite de l'experience, Blanchard, Paris, 1958.

4. F.E. Neumann, Vorlesunges uber elektrische Strome, Teubner, Leipzig, 1884.

5. P. Graneau, D.R. Sadoway, Electromagnetic jets offer large potential to metallurgists, *Industrial Research & Development*, December, 1982, p.98.

6. P. Graneau, Electrodynamic seawater jet: An alternative to the propeller? Proceedings of the IEEE Intermag '89 Conference, March 28-31, 1989, Washington, DC.

7. S.K. Yoder, Japan plans speedy superconducting ships, *The Wall Street Journal*, August 17, 1988.

8. F. Frungel, High speed pulse technology, Vol.I, p.477, Academic Press, New York, 1965.

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The PC graphics maze

Applications software has long since outgrown the graphics capability of the original IBM PC architecture. The hardware has more or less kept pace by evolving a series of graphics adaptors of increasing complexity, each with a different number of display colours and pixel definitions. We offer a programmer's guide to the IBM graphics maze.

KEITH WOOD

IBM designed a business machine which put text on a screen for day-long confrontation. Its monochrome display was good then and still is. Graphics developed as a direct result of its success, and its use in every rational and artistic field.

In the beginning there was the Monochrome Display Adapter (MDA), provided with a useful set of graphics characters identified by bytes in the range B0H to DFH. Boxes, tables and bar graphs could be constructed with them. Colour could be had in a limited way by adding the Colour Graphics Adapter (CGA), but character definition suffered. The scanning raster had fewer lines and the colour monitor phosphor array wasn't designed for close viewing.

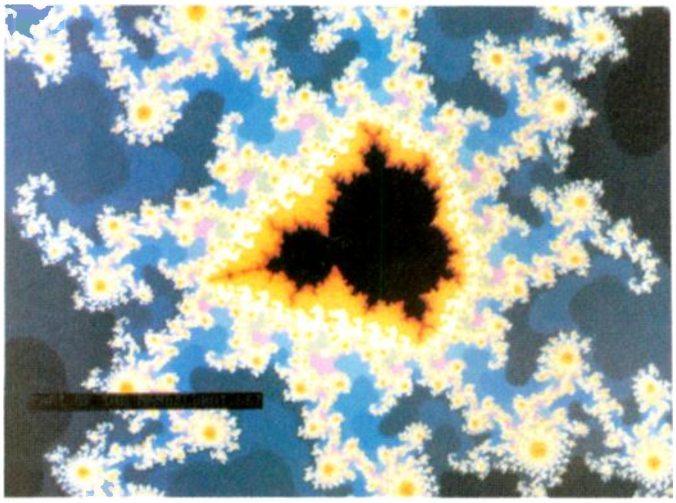
Graphics requires pixel addressing and therefore uses far more memory than text modes, which generate the video from the ascii codes using hardware. Development of advanced graphics has followed closely the falling price of mass memory.

The Enhanced Graphics Adapter (EGA) was introduced next, and most recently the PS/2 range. The Multi Colour Graphics Array (MCGA) is found on PS/2 models 25 and 30 and the Video Graphics Array (VGA) on the others.

Early graphics systems used plug-in boards, giving full rein to add-on equipment suppliers. PS/2 graphics sub-systems are built on to the motherboard; plug in VGA cards are for updating earlier models. Modern adapters exceed even the VGA specification, having half a megabyte of memory on the card. By contrast, the MDA had 4 Kbyte.

The memory used by the graphics system is addressable by the CPU either directly or using the service provided in the dos and bios. The graphics subsystem reads this memory when sending data to the display. The part of the CPU memory map allocated to the video system is from A000:0000H to B000:FFFFH, or 128 Kbyte (See box "Addressing the 8086 family memory").

Each enhancement incorporates enough of the display modes of earlier versions to maintain the utility of existing software. Monitors were fixed frequency; multi-sync is a recent phenomenon. Thus an EGA text mode, for example, is not identical to the CGA equivalent in raster terms, even though it may be in character terms. The difference is compensated by having an alternative character set.



A Video Graphics Array 16-colour display. Although only 16 are available, they can be chosen from 262144 and subtle effects are possible. The resolution is 640 horizontally by 480 vertically, and this is the only display mode available having equal pixel "size" both ways.

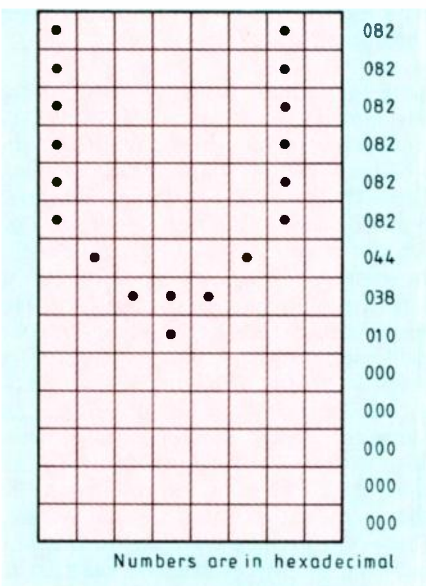


Fig.1. An 8×14 character array such as that supplied with the EGA. 9-pixel wide arrays are specified by the same byte, the video display circuits provide the extra pixel. MDA characters occupy the top 11 rows of 14, leaving row 13 for underline. The position of the underline is programmable and can also be displayed by the EGA in graphics mode.

CREATING THE DISPLAY

As a general rule, the video display should be created using the highest-level means appropriate to the task in hand. There are so many options that different application programmes will not necessarily address the video system in the same way. A pop-up utility may use different settings from the main task and cause disruption of the display. Such programs often state the applications software with which they are compatible. Using high-level services reduces this risk by presenting a constant interface. Low-level entry should be used only when an effect can't be obtained otherwise.

Languages such as Basic and C have graphics facilities either built in or in libraries. Some versions have functions for addressing the bios (basic input/output system) directly from the language.

The text services available through dos resemble the time honoured teletype. The graphics symbols used to produce tables and histograms can be handled through dos. Character and string handling routines in text mode are uniform and perhaps the worst that can happen is that the screen changes colour when a second application takes control.

Bios functions cover every requirement. In many cases the bios keeps a record of the settings sent to the video sub-system. An application or installation programme can call the more recent bios versions to find out what the settings are. Alternatively the bios data can be read. Writing to the video system bypasses the process and subsequent bios calls may crash the display. Such bugs are hard to trace as the fault is not at the point where the crash occurs. The bios facilities should therefore be used.

Where a video subsystem is provided by a third party, it either emulates the IBM systems, responding to bios calls, or it has a mode of its own, requiring direct addressing bypassing the bios. One such system is the original Hercules Graphics Adapter.

Programs using the bios are likely to have a longer life and wider application than those using direct access. The latter give greater speed and creative freedom, especially when writing pixels to the display memory. The bios call to write a pixel requires the colour, the row and column numbers and the display page for each pixel submitted. This is very slow when a large area is to be filled from a buffer. The actual call is INT 10H with AH=OCH, AL=pixel colour, BH=page, CX=column, DX=row. The same call with AH=ODH reads a pixel, which is returned in the AL register.

All bios video service calls are grouped into interrupt 10H, with the service required in AH register and the subservice usually in AL. The 80286 and 80386 generate interrupt 10H on chip after a co-processor error, such as overflow. To resolve a clash, additional code is required to look at the instruction just completed to see if it is INT 10H – video services. Suitable code may be present in the bios rom or in the rom on some of the more advanced video adapter cards.

Each issue of the bios rom has more services than the last. A recent estimate has 23 services arising from interrupt 10H, with a further 64 sub-services and even 10 sub-sub-services. Refer to the technical computer documentation for the subset in use. Later roms have all the earlier services, and are almost identical.

When the MDA and CGA were introduced, there were eight video modes of operation provided by the bios, 00H to 07H in **Table 1**. The EGA added four more, 0DH to 10H, and the VGA a further three, to 13H. These modes are invoked by INT 10H with AH=0, AL=mode.

TEXT DATA FORMAT

Whatever graphics system is in use, text mode data is stored in memory using two bytes per character. The first byte of a pair is the ASCII code for the character, while the second, the attribute byte, governs its appearance. In colour, the foreground (the character itself) and the background can each have any one of 16 colours (see below). Invisibility or reverse video is simply a matter of assigning appropriate colours. The bits in the second byte of the pair are assigned thus:

Bit	Significance in CGA mode.
0	Foreground blue
1	Foreground green
2	Foreground red
3	Foreground intensity
4	Background blue
5	Background green
6	Background red
7	Background intensity

Bit 7 has a second interpretation. It can cause the foreground colour to blink, while the background colour assumes the low intensity state. To enable this feature, it is necessary to set a bit in an I/O port (in CGA mode, bit 5 of port 3D8H).

The EGA, MCGA and VGA modes use each nibble to select one of 16 colours (see below). Blinking can be enabled using bios interrupt 10H with AH=10H, AL=03H and BL=1.

Table 1. The bios video modes.

AL	ADAPTER	TEXT chars × rows	DISPLAY pix × scans	CHARACTER MATRIX w x h	COLOURS	MEMORY start address	PAGES	MEMORY REQUIRED bytes/page	FRAME RATE Hz
00H*	CGA	40×25	320×200	8×8	16 of 16	B800:0000H	8	2,000	60
and	EGA		320×350	8×14	16 of 64	˝	8		60
01H	MCGA		320×400	8×16	16 of 262144		8		70
	VGA		360×400	9×16	16 of 262144	˝	8		70
02H*	CGA	80×25	640×200	8×8	16 of 16	B800:0000H	4	4,000	60
and	EGA		640×350	8×14	16 of 64	˝	8		60
03H	MCGA		640×400	8×16	16 of 262144		8		70
	VGA		720×400	9×16	16 of 262144	˝	8		70
04H	CGA				4 of 16				60
and	EGA		320×200		4 of 64	B800:0000H	1	16,000	60
05H*	MCGA VGA				4 of 262144				70
06H	CGA				2 of 16				60
	EGA		640×200		2 of 64	B800:0000H	1	16,000	60
	MCGA VGA				2 of 262144				70
07H	MDA EGA	80×25	720×350	9×14	mono	B800:0000H	1	4,000	50
	VGA		720×400	9×16	mono	˝	8		70
0DH	EGA		320×200		16 of 64	A000:0000H	8	32,000	60
	VGA				16 of 262144		8	32,000	70
0EH	EGA		640×200		16 of 64		4	64,000	60
	VGA				16 of 262144		4	64,000	70
0FH	EGA VGA		640×350		mono		2	28,000	60/70
10H	EGA		640×350		16 of 64	A000:0000H˝	2	112,000	60
	VGA				16 of 262144	˝	2		70
11H	MCGA VGA		640×480		2 of 262144	A000:0000H	1	38,400	60
12H	VGA		640×480		16 of 262144	A000:0000H˝	1	153,600	60
13H	MCGA VGA		320×200		256 of 262144	A000:0000H	1	64,000	70

These modes are invoked using INT 10H with AH=0 and the above mode number in AL.
*In these modes the colour burst signal is disabled in the composite output for monochrome monitors.
˝Signals interleaved memory.
Setting the video mode clears the screen. Resetting the same video mode is a handy way to do it.

Blinking occurs when bit 7 is set, leaving a choice of eight background colours. The same interrupt with BL=0 disables blinking and enables 16 colours.

In monochrome, there is an attribute byte in which bit 7 can also be enabled to cause blinking.

Attribute	Significance
00H	No display
01H	Underlined, lit character, dark background
07H*	Same, not underlined
09H	Bright character underlined
0FH*	Bright character
70H*	Reverse video

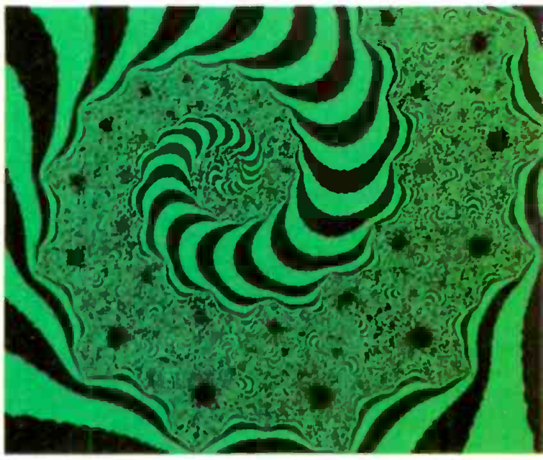
*Only these respond to bit 7. When blinking is not enabled, bit 7 increases the background on some monitors.

The data tables for character display are supplied by the bios. There are several different sets available, originally one based on a 9×14 pixel array for the MDA and one based on an 8×8 array for the CGA.

The four-byte address of the CGA character pixel data table for bytes 080H to 0FFH is to be found at 0000:007CH, or interrupt vector location 1FH. An application can substitute the graphics symbols by pointing this vector to its own pixel data table. The MDA characters are not available for substitution.

The EGA, MCGA and VGA permit the substitution of the entire character set, with bios calls for the purpose. The eight-pixel wide character array is conveniently specified as one byte per horizontal row (**Fig.1**). A table or part of a table can be substituted for the default using bios interrupt 10H with AH=11H, AL=0, the address of the table in ES:BP, the number of characters in CX, the ASCII code of the first character in DX and

A display created using the normal character set, with attributes.



A Hercules Monochrome Graphics display. Part of a Julia set associated with the Mandelbrot set. The resolution is 720 horizontally by 348 vertically, with an aspect ratio of 1.45.

Table 2. A summary of bios character calls.

TEXT MODE BIOS CHARACTER CALLS

FUNCTION	AH	AL	BH	BL	CX	COMMENTS
Read character at cursor location.	08H		Page			Returns Ascii in AL, attribute in AH
Write character and attribute	09H	Ascii	Page	Attribute	Number of repeats of the byte required	Cursor not advanced, wrap around available
Write character	0AH	Ascii	Page			Cursor not advanced, wrap around available, current attribute used
Write character in teletype mode	0EH	Ascii	Page (very early bios)			Cursor advanced, uses current attribute, wrap around and scroll

GRAPHICS MODE BIOS CHARACTER CALLS

FUNCTION	AH	AL	BH	BL	CX	COMMENTS
Read character at cursor location.	08H		Page			Returns Ascii in AL or zero if no match found
Write character and attribute	09H	Ascii	Page, or background colour for video mode 13H only	Foreground colour, black background; XOR applies	Number of repeats of the byte required	Cursor not advanced, wrap around not available
Write character	0AH	Ascii				Cursor not advanced, wrap around not available
Write character in teletype mode	0EH	Ascii	Page (very early BIOS)	Foreground colour		Cursor advanced, wrap around and scroll

XOR applies to the foregound colour if bit 7 is set on. The colour number supplied in BL is XORed with the existing colour for each pixel. All 1's creates reverse video. Read character (8H) in graphics mode works by pattern recognition, so if an alternate user supplied graphics character is sought, it still finds it and returns the byte describing it.

the number of bytes per character in BH. Characters nine pixels wide duplicate the right hand pixel (bit 0) or use the background.

The cursor consists of some scan lines within a single character having the foreground colour. Bios calls manipulate the cursor using INT 10H with AH=01H, set cursor size, AH=02H, set cursor position or AH=03H, read cursor position. For all three services, BH=page, CH=cursor start scan line, CL=cursor stop scan line, DH=row, DL=column. Scan lines count from 0. Bit 5 set in CH when AH=01H hides the cursor.

For normal purposes characters are most easily written by using dos through interrupt 21H. Function 02H or 06H in AH causes the ASCII character in DL to be written on screen. The cursor is adjusted. Function 09H in AH does the same for a string terminated with '$'. Function 06H will transmit any code from 00H to FEH; FFH changes the function to keyboard input. Later versions of dos permit redirection, so a file service could send data to the display, or one of the above services could be directed elsewhere. Dos function 040H is particularly useful.

Bios calls to write characters are involved, **Table 2** gives the necessary information.

Scrolling in a window uses bios (INT 10H) services AH=6 for up and AH=7 for down. CH/CL=row/column of the top left corner and DH/DL=row/column of the bottom right corner of the window. AL=number of lines to scroll and BH=attribute byte for the blank lines.

Character data for display in text mode is held in the video buffer at address B000:0000H (monochrome video mode 07H) or B800:0000H (CGA text modes 00H to 03H) whichever graphics adapter is in use. Because character data takes up little room in memory, up to eight different pages can be held and switched using further bios calls. The actual number of pages varies with the mode in use (Table 1). Pages start on 4kbyte boundaries in memory in the regular 80 column by 25 row text modes.

The EGA and VGA use interleaved pages in memory for characters and attributes; this is transparent as the hardware allocates bytes according to whether the address is odd or even.

An Enhanced Graphics Adapter display. The limited choice of colours results in obvious distinctions between regions. The resolution is 640 horizontally by 350 vertically.

A Video Graphics Array 256-colour display. The large number allows subtle graduations in a display, though the limited resolution of 320 horizontally by 200 vertically loses fine detail.

Where four planes of memory all have the same address, a CPU instruction to read a byte causes four bytes to appear on the data lines from the four planes. These bytes are intercepted by four latches. Control registers select one of these bytes to be returned to the CPU. Seen as an 8×4 bit array, reading across the bytes reveals eight 4-bit pixel values from consecutive screen locations.

A CPU write causes the contents of the latches to be written back to the memory planes, modified on the way by the settings of the control registers. A simple read and write cycle causes four bytes to be transferred without change from one place to another.

There are nine internal registers giving a large number of options in reading and writing: a single read and write operation is described here. The port at 3CEH receives the number of the register to be written to, and the port at 3CFH receives the data.

Read mode 0 is set at bit 3 of register 5 to read a byte. The select register 4 receives the number of the memory plane the byte is to come from. To read the first byte from plane 3 requires the following fragment of assembler:

```
mov   ax,0A000h          ;start of video buffer
mov   ds,ax              ;segment address
mov   ax,00005h          ;read mode 0 to R5
mov   dx,003CEh          ;port
out   dx,ax              ;word out writes both
mov   ax,00304h          ;plane 3 to R4
out   dx,ax
xor   si,si              ;first byte offset is 0
mov   al,ds:[si]         ;read the byte
```

A block may be read from the plane using a repeating movsb to a local buffer.

Write modes are pixel oriented: they access the latch array across the bytes. Mode 2 is set in bits 0 and 1 of register 5. There is a mask in register 8 to define which of the eight pixels is to be modified (1=change, 0=leave). The pixel data from the CPU consists of bits 0-3 of the byte sent. Register 3 is set to 0 in this case, it controls extensive bit twiddling facilities.

```
mov   ax,0A000h          ;start of video buffer
mov   ds,ax
mov   ax,00205h          ;write mode 2 to R5
mov   dx,003CEh
out   dx,ax
mov   ax,06408h          ;bit mask 01100100
                          to R8
out   dx,ax
mov   ax,00003h          ;0 to R3
out   dx,ax
xor   si,si              ;first byte
mov   BYTE PTR ds:[si],  ;send pixel value 13
      00Dh
```

The existing pixel values have to be read to the latches before the write, or random data will be sent. If the eight pixels are to be all different (very unlikely) the read and write process will be repeated eight times. Tedious. If all eight pixels are to be the same (very likely) they are all done in one write. Larger areas only require incrementing addresses as register data stands until changed.

A WRITE PROCESS

```
Latches                              Memory planes

00000000---o-  --  --->01100100
00000000---  -o--  --->01100100
00000000---  -  --  --->00000000
00000000---  -  --o--->01100100

        xxxx1 10 1         01100100
        CPU data            bit mask
```

A READ PROCESS

```
Memory planes            Latches

01100100---o->01100100<
01100100---  ->01100100
00000000---  ->00000000
01100100---  ->01100100

  01100100-'
  data to CPU
                 xxxxxx11
                   select register
```

Saving and restoring a bit map requires some data manipulation. It is a wise precaution to reset default register values after any operation.

GRAPHICS DATA FORMAT

When in a graphics mode, characters can still be displayed. The bios keeps a record of a phantom cursor and places characters accordingly, accessing the character tables for pixel data and writing it to the video display buffer rather than direct to the screen. To make the cursor visible write one of the graphics characters to the reported cursor position. Bios services move and report its position as in text modes.

Each pixel is specified separately in graphics mode. Even at one bit per pixel the memory requirement is much larger than in text modes. It is vital to compress the data as much as possible not only to save memory, but to make it possible to read the memory fast enough to keep up with the raster.

The system employed is akin to painting by numbers. One bit per pixel can have the value 0 or 1 which specify two colours. The actual colours referred to by 0 and 1 are chosen in advance from all the colours available to the particular video subsystem. Two bits can specify four colours, up to eight bits can specify 256 colours (Table 1).

The number of possible colours is larger than the number that can be displayed. The descriptors of the chosen subset are placed in a table known as a palette. The bits describing a pixel are read from the video buffer, and used to select the corresponding entry in the palette. This entry is used to generate the video signal.

In CGA mode, there are 16 possible colours. These are provided by red, green and blue, each of which can be on or off, combined with two overall levels of intensity.

The CGA does not give a free choice of colours for the palette. In mode 04H, two bits per pixel, there is a choice between two permanent palettes, green, red, brown or cyan, magenta, white for 01, 10, 11 respectively. Mode 05H allows cyan, red, white only. In each case 00 can be any one of the 16 colours. Mode 06H, two colour mode, permits free choice for 1 while 0 is black. Bios service 0BH (INT 10H, AH=0BH) has two subservices. BH=0 and BL=colour sets the free choice which is also used for the border except in video mode 6. Bit 5 of BL then sets the palette choice. Otherwise, BH=1 sets the palette choice by BL=0 or 1 respectively.

All the CGA graphics modes access data in the video buffer starting at address B800:0000H. Each byte is read left to right; in two colour mode bit 7 of the byte at offset 0000H represents the top left pixel, bit 6 the pixel immediately to the right of it and so-on. The next scan line (an odd numbered line) accesses memory at B800:20000H in

TWO CHIP VGA GRAPHICS

It is now possible to purchase VGA graphics on a two-chip set providing all the control functions of a 256-colour palette. The Cirrus logic GD510/520A devices provide register and bit level compatibility with all the popular software written for IBM graphics standards including the newest VGA. The same company also supplies an extended 16-bit bios to enhance the performance of the standard 8-bit offerings.

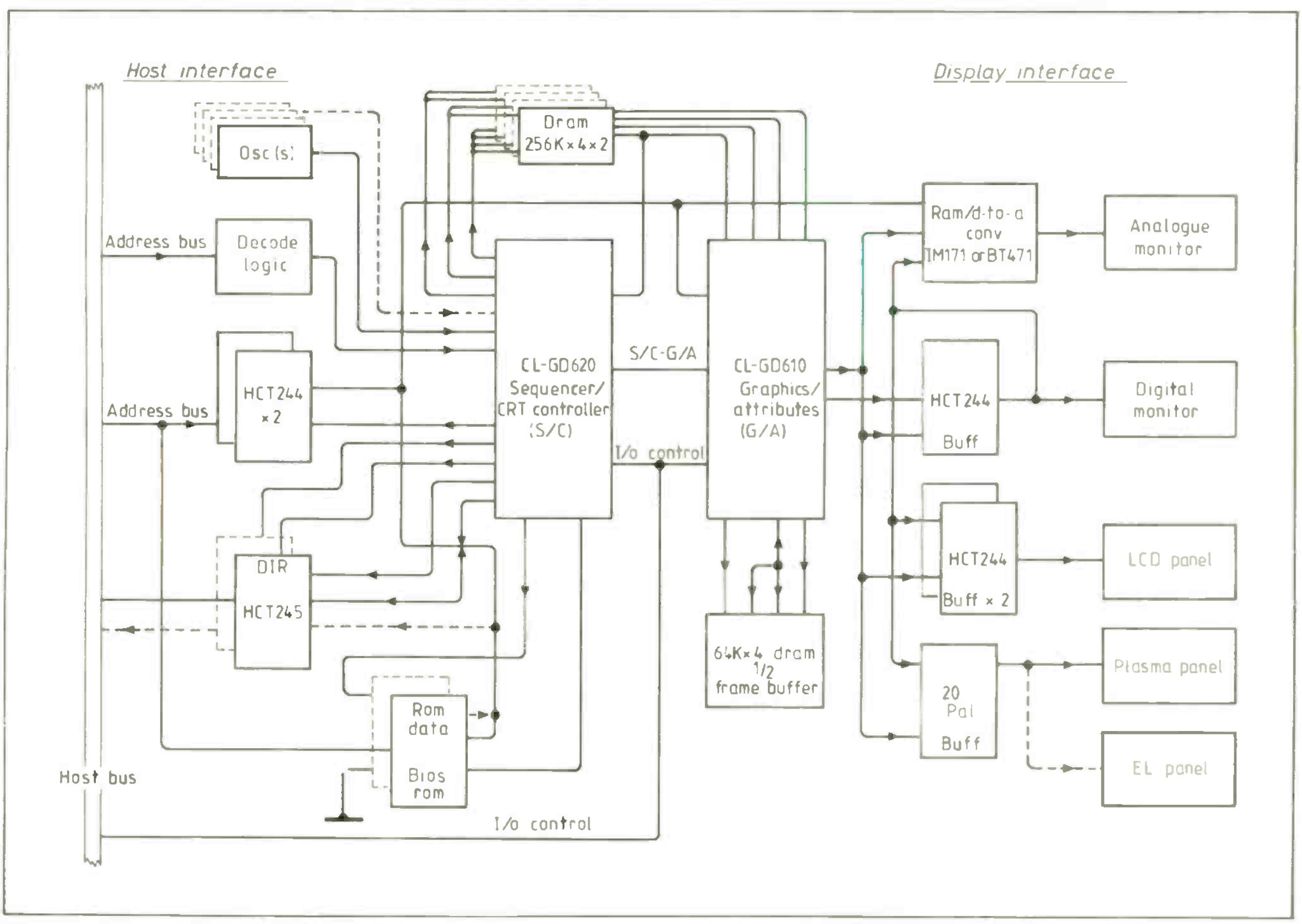
Analogue monitor implementation requires an additional 256K of ×4-dram, video dac and bus interface circuitry in addition to the extended bios which forms part of the package. The CL-GD510A Graphics/Attributes chip and the CL-GD520A Sequencer/CRT Controller chip are hardware-compatible with the IBM Hercules VGA, EGA, CGA and MDA standards, as well as with the Hercules HGC. The company has a version appropriate to lap-top LCD screens.

Operating at dot clock rates up to 40MHz, the chip set supports high resolution graphics and alphanumeric display modes for both monochrome and colour, and for high resolution variable frequency and PS/2 monitors. Video outputs are provided in four bits per pixel (all resolutions) and eight bits per pixel (320 × 200). Using analogue video output and an external palette, selection may be made from 256K colours.

The set implements control and data registers in the current graphics standards appropriate to the 6845 CRT controller. It also includes data manipulation capabilities and data paths, providing complete hardware and software compatibility.

The sequencer design provides additional video memory cycles for the CPU during the normal video refresh/display cycle. Memory cycles not used to refresh the display or video memory can be allocated to process CPU memory requests.

The hardware supports a mouse/graphic cursor, and a blinking insertion point text cursor together with an independent smooth scrolling of two separate text screens.



the same way, and the third scan line (even) data follows that of the first line. Even and odd numbered lines occupy two distinct blocks of memory.

EGA provides a choice from 64 colours. Two bits specify each of the primaries, giving three coarse steps in brightness and off. Sixteen choices are loaded to the palette, with defaults corresponding to the CGA colours, which in turn has a six bit entry to specify six inputs to the monitor where they are combined. Each byte loaded has the form 00rgbRGB, and a 17th byte specifies border colour. Rr represents the two-bit value for the red component, and so on.

VGA and MCGA both use a video digital-to-analogue converter (DAC). It has its own array of registers holding 256 colours available for display. Each primary colour is specified by six bits; the colour descriptor has 18 bits providing 262144 possible choices.

VGA and EGA have 640×480×16 and 640×350×16 modes respectively. These require 150 and 110kbyte of memory, to be read 60 times a second. The memory is divided into four pages of 64 kbyte, all of which have the same address starting at A000:0000H and which are read in parallel. In use, bit 7 of the first byte in each of the pages 3,2,1,0 in that order yields a four-bit number specifying 1 of 16 palette entries for the top left pixel.

As four memory planes have the same address, CPU access requires the intermediary of four latches. Read or write to the video memory transfers four bytes to or from these latches. See the box "Writing to interleaved memory".

MCGA does not implement the 640×480 16-colour mode, and its memory requirement is limited to 64 kbyte. This and all other modes use the video buffer to supply a single continuous bit stream read from A000:0000H on.

VGA has one other enhancement over MCGA, it has a 16 colour palette as well as a 256 entry array. In 16 colour modes the pixel data selects from the palette which in turn selects from the 256 entry array. In 16 colour mode the MCGA uses the first 16 colours in the array.

VGA uses the palette to page the array, specifying any block of 16 entries or 16 from any block of 64 entries. Bios call INT 10H

Table 3. A sample of the colour handling BIOS calls available using INT 10H with AH=10H.

Title of service	Adapter	AL	BH	BL	Comments
Load a palette register	EGA VGA	00H	new colour descriptor	palette register number	
Read a palette register	VGA	07H			Colour descriptor returned in BH
Load a palette register	EGA VGA	02H			A 17 byte table in data memory is specified in ES:DX. the 17th byte is the border colour
Read a palette register	VGA	09H			
Load a video DAC register	MCGA VGA	10H	BX=register number		Data supplied or returned in 6 bit quantities. DH=red, CH=green and CL=blue.
Read a video DAC register	MCGA VGA	15H	BX=register number		
Load a video DAC block	MCGA VGA	12H	BX=number of first register in the block		The address is ES:DX is of a table of 3-byte colour values red, green, blue.
Read a video DAC block	MCGA VGA	17H	CX=the number of registers		
Change video DAC page	VGA	13H	00H 01H page number	00H 00H 01H	Use 64 register pages Use 16 register pages select page number

ADDRESSING THE 8086 FAMILY MEMORY

The 8088/8086 CPU is a 16-bit machine, but has 20 address lines. There is therefore 1Mbyte of addressable memory. A 16-bit word can only address 64Kbyte, a block of memory called a "segment". The 16-bit address within the segment is called an "offset". A segment can be placed anywhere in the 1 megabyte addressing range by adding a constant to the offset to generate a physical 20-bit address. This constant is the segment address and it has by definition four zeros for the four low-order bits of the 20. These zeros are not recorded and the segment address is a 16-bit value which is shifted four places left before adding the offset.

The address is written as 2345:5432H where the segment address is 2345H and the offset or pointer 5432H. When computing the physical address the shifts are included automatically by the CPU.

23450H	segement address
5432H	offset
28882H	physical address

Unless specified otherwise, coding is assumed to be within a given segment and only the offset address appears in instruments. Thus code can be loaded and run anywhere in memory without modification. It is also faster as an address fetch is only two bytes.

Four segment addresses are maintained in registers within the CPU, code, data, stack and extra. The assembler and the CPU distinguish between these and generate code accessing the right segment address automatically. The offset for the code segment is the instruction pointer, and for the stack segment the stack pointer. The instruction and stack pointers are automatically incremented and decremented, and SI and DI registers may also be incremented or decremented depending on the instruction and the direction flag. A full address in registers would be written ES:BP, for example.

In memory, a four byte address is used as one entity in the interrupt vector table. The address is stored as two 16 bit words, the offset at the vector address and the segment at the vector address + 2. Each word is stored least significant byte at the address, the other at the address + 1. The vector address is four times the interrupt number. Thus interrupt 10H has its vector address at 0000:0040H to 0000:0043H.

Available registers are:

	15 8	7 0	
AX (16 bit)	AH	AL	manipulate as either 8 or 16 bit registers
BX (16 bit)	BH	BL	
CX (16 bit)	CH	CL	
DX (16 bit)	DH	DL	

BP	base
SI	index
DI	index
SP	stack pointer
CS	code segment
DS	data segment
SS	stack segment
ES	extra segment
F	flags
IP	instruction pointer

These are common to the 8088/8086, 80286 and 80386. The latter have further registers in addition, used for addressing memory beyond the 1 megabyte memory and in multitasking.

The memory map is:

		High limit
Extended memory	80286/386 only	100000H
Rom bios		E0000H
Installable rom		C0000H
Video buffer		A0000H
		Installed ram limit
Dos transient code		
Transient programme area (TPA)		
Dos resident code		
Rom bios/Basic data		00500H
Rom bios data		00400H
Interrupt vectors		00000H

The 640kbyte limit is set by the dos which will not load programmes and data above this address, but will load a programme into the TPA which contains instructions to write to memory above that limit.

The 8086 and 8088 are identical as far as programming is concerned. The 8086 is faster in operation having a 16 bit data bus where the 8088 data bus is 8 bit. The 80286 and 80386 in "real" mode use the low-address megabyte of memory in exactly the same way. The 80286 also has a 16 bit data bus, but is faster again through instruction pipelining and internal improvements. The 80386 has a 32 bit bus.

Not surprisingly, bios makes no provision for the Hercules graphics mode. It is necessary to set the display controller, a Motorola 6845, by direct access. Consequently the method does not fit into the classification used in describing the IBM graphics modes. The code below was used to load the display of Fig.3, and illustrates the method. There are other makes of adapter and there are colour cards by Hercules. It is assumed that a file of pixel data exists having one pixel per byte (wasteful, but simple) in which the pixels are in the usual page-of-test order. The pixel values are 0 black or 1 lit.

```
        TITLE   HGCLOAD
        DOSSEG
        .MODEL  small
        .STACK  100h
        .DATA
;Default BIOS data to replace possible prior changes.
biosd   DB      7               ;crt_mode
        DW      80              ;crt_cols
        DW      08000h          ;crt_len
        DW      0               ;crt_start
        DW      8 DUP (0)       ;curs_posn
        DB      0               ;curs_mode
        DB      0               ;act_page
crtcad  DW      003B4h          ;addr_6845
crtmod  DB      00Ah            ;crtr_m_set (for 3B8h)
        DB      0               ;crt_pal (unused)
biodln  EQU     $-biosd
;Motorola 6845 CRTC settings for 16 pixels × 4 scans/character
crtcdt  DB      000h,035h       ;horiz. total 54 chars.
        DB      001h,02Dh       ;horiz. displayed 45
        DB      002h,02Eh       ;horiz. sync posn. 46
        DB      003h,007h       ;horiz. sync width 7
        DB      004h,05Bh       ;vert. total 92 rows
        DB      005h,002h       ;vert. adjust 2 scans
        DB      006h,057h       ;vert. displayed 87 rows
        DB      007h,057h       ;vert. syn posn. 87
        DB      009h,003h       ;4 scans/character
crdtln  EQU     ($-crtcdt)/2    ;read by word access
pixbf   DB      23040 DUP;input buffer, 1 (?)   byte/pixel
pbfln   EQU     23040
; 23040 = 8 passes × 4 planes × 90 bytes × 8 pixels
inphan  dw      0               ;pixel source file handle

        .CODE
                ;access data file and place handle in inphan,
                ;DGROUP to ds then continue as follows:
start:  cld                     ;index upwards
        mov     ax,00040h       ;BIOS data area
        mov     es,dx
        mov     di,00049h
        mov     si,OFFSET biosd
        mov     cx,biodln
        rep     movsb           ;reset video mode 7 data
        mov     dx,003BFh       ;configuration switch
        mov     al,1            ;graphics on, page 1 off
        out     dx,al
; blank the screen
        mov     dx,003B8h       ;CRTC mode control port
        xor     al,al           ;bit 3=0 disables video
        out     dx,al
;programme the CRTC
        mov     dx,003B4h       ;CRTC address port
        mov     si,OFFSET crtcdt
        mov     cx,crdtln
hgcl:   lodsw
        out     dx,ax           ;al=reg. no., ah=data
        loop    hgcl
;set graphics mode
        mov     dx,003B8h
        mov     al,crtmod       ;enable graphics + video
        out     dx,al
;load the pixels
        call    fillbf
        mov     si,OFFSET pixbf
        mov     ax,0B000h       ;video buffer address
        mov     es,ax
        xor     di,di
        mov     dl,87           ;87 lines per plane
fill1:  mov     dh,4            ;4 planes
fill2:  mov     bh,90           ;90 bytes per scan line
fill3:  mov     cx,8            ;8 pixels per byte
        xor     bl,bl
fill4:  lodsb
        shr     al,1            ;pixel to carry
        rcl     bl,1            ;and into bl
        loop    fill4
        mov     al,bl
        stosb                   ;byte to video buffer
        dec     bh
        jnz     SHORT fill3     ;for 90 bytes
        add     di,02000h-90    ;next plane
        dec     dh
        jnz     SHORT fill2
        sub     di,08000h-90    ;back to plane 0
        mov     al,7            ;mask for group counter
        and     al,dl
        jnz     SHORT fill5     ;every 8 passes refill
        call    fillbf          ;the byte buffer
fill5:  dec     dl
        jnz     SHORT fill1     ;87 times
        jmp     $               ;reset when tired of it
fillbf: push    dx
        push    di
        mov     bx,inphan
        mov     cx,pbfln
        mov     dx,OFFSET pixbf
        mov     ax,03F00h       ;read input file
        int     021h            ;to buffer
        mov     si, OFFSET pixbf
        pop     di
        pop     dx
        ret
        END     start
```

with AH=10H, AL=13H, BL=0 and BH=0 sets 64 entry blocks or BH=1 for 16 entry blocks. The same call with BL=1 takes the value in BH for the required block number.

The first 16 entries in the video DAC and the 16-colour EGA palette have default settings corresponding to the CGA colours. The second 16 in the video DAC constitute a grey scale: all 256 entries have default settings.

A sample of the bios calls available through INT 10H for specifying colour selections can be found in **Table 3**.

The latter graphics modes can be modified through the use of a range of masking bytes and enabling bits. There are too many to describe here, and their actions do not condense into neat classifications. The defaults are adequate usually. This article assumes defaults are in force.

This lap-top computer includes a Cirrus Logic VGA chip set for PS/2-type graphics.

MONOCHROME GRAPHICS

Services 0, 02H and 05H generate a monochrome signal from the CGA composite output by disabling the colour burst signal. The R,G,B outputs are unaffected. Service 5 creates a four-level grey scale: services 0 and 2 provide a variable number of shades from the colour attributes. These services are otherwise identical to services 1, 3 and 4 respectively.

Service 6 is one colour and black, which is effectively monochrome on a colour monitor.

Service 7 is the MDA and service 15 provides a monochrome signal from EGA and VGA systems. These services require a direct drive monochrome monitor, as opposed to the composite input monitor required by the CGA.

Operation of these services is the same as the corresponding colour services described above.

ACKNOWLEDGEMENT

I would like to acknowledge the help received from Rapid Computers Ltd., of Childwall Fiveways, Liverpool L15 6XX, for the use of their range of demonstration PCs.

BIBLIOGRAPHY

The New Peter Norton Programmer's Guide to the IBM PC and PS/2. Peter Norton and Richard Wilton. Microsoft Press. ISBN 1-55615-131-4.

Programmer's Guide to PC and PS/2 Video Systems. Richard Wilton. Microsoft Press. ISBN 1-55615-103-9.

IBM Technical Reference Manuals for the various models.

ACTIVE

Asic

28-pin pal device. The PALCE26V12H, fabricated in an electrically erasable c-mos process, is an extension of the AMD 24-pin PAL12V10 architecture. The 26V12 boosts the 22V10's functionality by about 20 percent and offers more inputs, outputs and macrocells than the 22V10 and a second clock. Advanced Micro Devices (UK) Ltd, 04862-22121

A-to-D and D-to-A converters

Voltage-output D/A converter. The AD7846 digital-to-analogue converter uses a segmented-ladder architecture to ensure 16 bits of both resolution and monotonicity. It is fabricated in BiCMOS and includes track-and-hold output amplifiers to generate a low-glitch buffered voltage output. To permit the microprocessor to write data and verify it, the AD7846 incorporates a readback feature. Analog Devices, 0932-253320

Triple 8-bit palette DAC. The IDT75C458 is a triple 8-bit video d-to-a converter with on-chip, dual-ported colour palette memory, designed for high-resolution colour-graphic display applications. The architecture of the IDT75C458 eliminates the ECL pixel interface by providing multiple TTL-compatible pixel ports and by multiplexing the pixel data on-chip. Microlog Ltd, 04862-29551

20MHz 8-bit video ADC. The single-chip, 20MHz, 8-bit video ADC, SP94308, is fully compatible with both NTSC and PAL video signals and accepts an AC-coupled input of 1V pk-pk. Plessey Semiconductors, 0793-36251

Development and evaluation

H16 evaluation card. The EVC641016 evaluation card allows applications of its 32-bit H16 microprocessor to be developed and tested in the IBM PC environment. The card consists of a single IBM PC XT format PCB containing the H16 CPU, control logic, and an RS-232C interface, an IBM bus interface and a variety of I/O signals. Hitachi Europe, 0923-246488

General microprocessors

10MHz H16. The HD641016CP-10 is a 10MHz version of the H16 embedded controller. The device is built in 1.3μm c-mos and contains a 32-bit CPU, 1Kbyte of fast, on-chip static ram and a comprehensive set of peripheral circuits. The H16 architecture has been specifically designed to support C and other high level languages. Hitachi Europe, 0923-246488

16-bit single-chip microcomputer. Mitsubishi's 16-bit single-chip microcomputer family is now available. The Mitsubishi 7700 series microcomputers are available in 8MHz or 16MHz versions, resulting in a minimum instruction cycle time of only 0.25μs. On-chip memory sizes are the largest currently available from any manufacturer – either 16Kbytes rom with 512 bytes ram or 32Kbytes rom with 2Kbytes ram. Eprom and OTP (one-time programmable) versions are also available for development work and low volume applications. Impulse Electronics, 0883-46433

Microcontroller. The OTP Z8 integrates the Zilog c-mos Z8 microcontroller with 8K bytes of one-time-programmable rom. Designated the Z86E2116, the Zilog OTP Z8 is a field-programmable device designed for use by engineers as a code development tool. Microlog, 04862-29551

Interfaces

Intelligent STEbus serial I/O. A new four-channel serial I/O STEbus board, SISER4, offers local processing power using the CLIP control language, and memory for dual-port control and data buffering. CLIP is a new standard high-level control language for intelligent peripherals. Arcom Control Systems, 0223-411200

Linear integrated circuits

Four-channel video multiplexer. The AD9300 provides four-to-one-channel switching for video signal routeing and medical imaging. A typical full-power bandwidth of 34MHz (30MHz minimum) and small-signal bandwidth of 350MHz are combined with ±0.1dB gain flatness to 8MHz. Any of the four inputs can be randomly switched to the output at rates of 20MHz or higher with a two-bit channel-select code. Analog Devices, 0932-253320

Quad bifet op-amp. The AD713 is a new monolithic quad operational amplifier which, in addition to settling to 0.01% in 1μs (10V step), offers an input offset voltage of 0.5mV and a bias current of 40pA, harmonic distortion of 0.0003% at 3V RMS, a slew rate of 18V per microsecond and minimum common-mode rejection of 84dB. Analog Devices, 0932-253320

C-mos operational amplifiers. Exhibiting an input impedance to j-fet types and extremely low input offset (2-10mV) and bias currents, the TS27XX family of op-amps are pin compatible with, and suitable replacements for, most j-fet and bipolar types. These devices operate at up to 12V and are suitable for use with single rail supplies. Impulse Electronics, 0883-46433

Low-cost op-amps. Motorola's MC33170/MC34180 series op-amps have a significantly improved bandwidth and output voltage swing with no deadband cross-over distortion. Other benefits include a capacitive drive capability of 10 000pF and power consumption of 180μA per amplifier. Features of the device include a 13V/μs slew rate and 4.5MHz bandwidth. Jermyn Distribution, 0732-450144

Video line driver. Two new integrated video line drivers, VS620 and VS621 from VTC, are designed to be fully compatible with SMPTE RP 125 requirements. Both devices are 10 bits wide, parallel-format line drivers providing differential outputs for 10 data bits and one clock bit. Outputs are 10k ECL compatible, and the devices operate from a 27MHz interface clock. Mogul Electronics, 0732-741841

Satellite prescaler. A divide-by-two prescaler IC for satellite television receivers can also be used as a frequency divider in high-frequency measuring equipment. The IC, SAB8726, has a guaranteed input sensitivity of −10dBm (70mV RMS) and a frequency range from 1GHz to 2.6GHz. It accepts a sinusoidal signal from the local oscillator of a satellite television tuner and provides an input which drives the loop of the frequency synthesizer. Philips Components Ltd, 01-580 6633

Negative linear regulator. The IPIR19 series of fixed-voltage negative regulators is guaranteed to give 5A output over the full operating temperature range. They are available with output voltages of 5, 12 and 15 volts, with the "A" series offering ±1% output tolerance. The devices give line regulation of 0.01%/V and load regulation of 0.5%, both of these over the full specified operating conditions. Seagate Microelectronics Ltd, 0506-416416

Memory chips

150ns 2Mbit eprom. Organized as a 262 144 × 8bit device, NEC's μPD27C2001 2Mbit c-mos eprom family offers access times of 150, 170 and 200ns for the D-15, D17 and D-20 models respectively, whilst consuming a maximum active current of only 50mA. This reduces to 100μA in standby mode. 2001 Electronic Components, 0438-742001

1Mbit flash eprom. Samples of the one megabit flash eeprom 27F010 are available. The device is specified to erase and reprogram at room temperature and can endure up to 100 cycles. It features sector erase, allowing its 128 sectors of 1024 bytes each to be individually erased and reprogrammed, and it can also be bulk-erased in less than five seconds. Amega Electronics, 0256-843166

ETA chassis-mounting relays from Silicon Power Cube provide zero-switched, opto-isolated output of 4kV RMS

Silicon file memory chip. Silicon-file memory chip, μPD42601 is designed to enable solid state storage to be constructed with megabyte or even gigabyte capacities and with access speeds hundreds of times faster than hard disk drives. The chip features a self refresh current as low as 30μA and has a memory capacity of 1048 576 × 1bit. Very high packing densities enable a compact "silicon disk" unit with a 40Mbyte capacity to be constructed with an access time of 0.1ms and a data transfer rate of up to 20Mbyte/s with a 32-bit data word. NEC Electronics (UK), 0908-691133

Power semiconductors

Mosfets. The DIII series power mosfets by Hitachi includes logic-level drive capability, improved gate protection, higher breakdown voltage and narrower threshold voltage. Impulse Electronics, 0883-46433

Power mosfet drivers. The Maxim MAX626/627/628 each contain two high output current drivers which have been optimized to turn large power mosfets on and off quickly. Besides power fets, the new devices drive relays, charge pump circuits and pulse generators. The MAX626 has two inverting channels, the MAX627 has two non-inverting channels and the MAX628 has one inverting and the non-inverting channel. Thame Components, 0844-214561

Surface-mount rectifiers. General Instruments' surface-mount Superectifiers are a range of Jedec-registered glass passivated silicon devices. These 1A 50-1000 PRV, leadless, surface mounted devices that provide new space options from increased surface density at reduced bond size. VSI Electronics (UK), 0279-35477

PASSIVE EQUIPMENT

Passive components

Multi-chip capacitors. A range of large custom, multiple ceramic capacitors housed in DIL and modular packages are for use in high-frequency filter applications in switched-mode power supplies. A wide range of capacitance is possible, and by using multi-chip techniques, values up to 100μF can be achieved. Voltages range from 50 to 500V DC. AVX, 0252-333851

Low profile dual beam socket. The C93 and C84 series sockets from Texas Instruments have been designed for high volume use. Features include an anti-wicking wafer design to protect against flux or solder contamination, wide protected open entry for ease of IC insertion, and dual beam-edge grip contacts. VSI Electronics (UK), 0279-35477

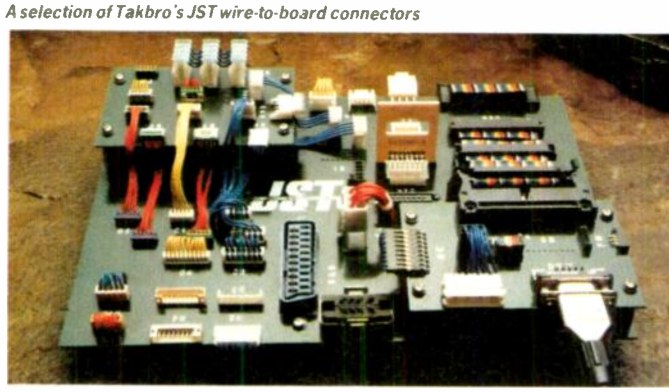
Connectors and cabling

Burn-in test socket for SMDs. The 639 series burn-in SOJ sockets from Wells Copeland allow surface mount device tests up to 150°C. The sockets provide fully enclosed contacts and the top of the socket provides a pre-insertion nest for self alignment of IC pins. Dage (GB), 0296-393200

Interface modules. Modules based on the Series 20,000 rail mounting components provide a wide range of interfacing connections. They provide a transition from barrier strip discrete wiring to IDC flat ribbon cable or D sub-miniature connector computer wire. Entrelec (UK), 0273-570730

Wire-to-board connectors. JST of Japan offers a range of wire-to printed circuit board

A selection of Takbro's JST wire-to-board connectors



MGP miniature stainless steel piezo accelerometers from Entran

connectors, designed to minimize PCB space requirement. The range includes both crimp and insulation displacement types, with pitches from 2.0 to 6.2mm. Single pole types are also available. Takbro, 0446-45601

Circuit protection

Suppressors. The SAB range of p-n transient suppressors from General Semiconductor Industries, marketed under the name Transzorb, is capable of dissipating 500 watts of peak pulse power for 1ms. Stand-off voltages range from 5 to 28 watts. RR Electronics, 0234-270272

Displays

Tri-colour led. The SPR54MVW led from Rohm is a three-lead bi-colour device with red and green chips in the same 5mm package. The three-lead arrangement enables the red and green leds to be separately biased and by mixing the red and green light a third amber colour is produced. Hero Electronics, 0525-405015

Instrumentation

Data acquisition system. The MC80000 series of extremely high-speed, high I/O, wide dynamic range, data acquisition systems offers speeds from 1 to 2000 000 samples a second at full 16-bit accuracy. Databasix, 0635-37373

Process monitor and controller. The PM-5070 is an intelligent panel-mount instrument designed for strain gauge and other bridge-type measurement applications. It includes a high-accuracy 10V excitation output and two input channels: one ±50mV input for connection to the bridge output and one ±10V input for excitation sense measurement. A ratiometric measurement mode automatically compensates for excitation drift and lead wire resistance, whilst input gain and offset errors are corrected automatically. Datel, 0256-469085

Digital multimeter. The Rohde and Schwarz UDL44 multimeter has five AC ranges from 250mV to 750V and five DC ranges from 250mV to 100V. Accuracy is within 0.04%. It measures current from 10nA to 1 and 10A. Frequencies between 10Hz and 100Hz can be displayed as such or as a period measurement. Feedback Instruments, 0892-653322.

60MHz oscilloscope. The Hameg HM604 oscilloscope is a universal 60MHz unit which fetaures an automatic-after-delay trigger mode, for jitter-free measurements of asynchronous signal sections, bursts or pulse trains, independent of amplitude fluctuation. Feedback Instruments, 0892-653322

Audio and acoustics. Audio Precision System One provides a full set of audio/acoustic measurements to international standards, controlled by an IBM, PC, AT or clone. Menu-driven software provides multi-parameter tests which can be further linked into complex procedures including go/no-go limits. Swept measurements include noise, frequency response, CMRR, THD±N, IMD, third-octave band filtering, phase, crosstalk, wow and flutter and polarity. The instrument permits examination of DAC and ADC performance up to 20 bits linearity. Island Acoustics, 0983-297780

Universal counter. The Stanford universal counter offers high-accuracy measurement of time intervals, frequency, period, pulse width, phase, and rise and fall times. It gives high-resolution measurements over the frequency range 0.001Hz to 1.3GHz. Event counting up to 200MHz is also achievable. Resolution for single-shot operation is 4ps. Lambda Photometrics, 05827-64334

Wattmeters. INFRATEK 104B (single phase) and 304B (three phase) precision wattmeters accurately measure complex signals produced by power switching devices. They determine the RMS value, the rectified mean value and the mean value of current and voltage, power, apparent power, reactive power, power factor, energy, charge, and impedance in one measurement cycle for one- and three-phase systems. Both wattmeters combine broad bandwidth (104B, DC-400 kHz; 304B, DC-100kHz) with wide measurement range (2mA-200A, 2V-1000V), and 0.1% accuracy. Lyons Instruments, 0992-467161

100MHz DSO. The 100MHz Trace 8608 has an integrated equivalent sampling rate of 4Gsample/s for repetitive waveforms and a full eight bits of vertical resolution. Real-time single-shot traces are digitized at 40Msample/s. It has a flip-up, flat-screen electroluminescent display and a 100-trace internal memory. Reflex Technology, 0494-814208

Transmission analyser. The SI 7714 performs transmit and receive functions at the four major data rates standardized by the CCITT for interconnecting digital transmission systems, that is 2, 8, 34 and 140Mbit/s. Schlumberger Instruments, 0252-544433

Printers and controllers

Colour video printer. The CP-100B is a full-colour video copy processor which is capable of producing hard-copy images of almost photographic quality from a video picture in 80 seconds. It can also accept images from graphic display monitors as well as conventional television systems. Mitsubishi Electric UK, 07072-76100

Production equipment

Automatic wave-soldering. The Super Nova automatic wave-soldering system, has overall package dimensions of only 72 × 22 × 16 inches. Only 38.6kg of solder is needed to fill the solder pot. The bi-directional solder wave has ¼in usable height and is controlled and stabilized by laminar-flow side plates. Hollis Europe, 0634-716733

Power supplies

Modular power supplies. The Powercube Goldline range consists of separate modules or "Cirkitblocks" which perform different functions within the power supply, for example filtering, input and output. These can be individually designed-in to customer circuits or combined and fully interconnected in a variety of ways to provide AC-DC or DC-DC conversion. Norbain Technology, 0734-864411

VME power supply. The VME003 pluggable VMEbus power supply has fully independent outputs which are permanently protected against short circuit and idling. Operating from either 110 or 220V (40-400Hz), this 6U/12HP power supply has outputs of +5V/35A, +12V/6A and −12V/2A. The PSU also features soft start and fold-back (up to $2/3I_{max}$). Schroff UK, 0442 40471

Switch-mode power supplies. The P series of single-output, switch-mode power supplies operate from an input of 85-264V, the larger models (up to 600W) having automatic AC voltage selection. Outputs of 5, 12, 15 and 24V are provided. Efficiency is typically 80% line and load regulation 0.5%. Ripple and noise are quoted as less than 150mV pk-pk for all units. Operating temperature is 0-50°C, output adjustment ±10%, isolation 3750V AC and all units have overvoltage, overload and short circuit protection. The 300 and 600 watt models have the facility for parallel operation. All models comply with UL, CSA and VDE safety standards. XP plc, 0734-576211

Switches and relays

Security relays. For security systems, reed relays based on the DYAD switch have been developed to offer users the advantage of no polarity and no interface problems, with the additional benefits of noise immunity, power handling, line-drive and line receive, the DYAD switch can handle loads from 0 to 10 watts. C.P. Clare International NV (Belgium), 010 12 23 33 11

Dual-in-line switches. New version of the Grayhill Series 76 and Series 78 families of dil switches have a new epoxy to seal the switch bases for higher thermal ratings. The new formulation also offers an improved seal. Highland Electronics, 04446-45021

Miniature power relay. A single-pole PCB-mounting relay type TRK 17, measuring 21.2 × 16.2 × 14.2mm, switches up to 7A at up to 1800 operations per hour. The silver-plated contacts can switch loads as low as 0.1A at 5V DC. A low-power version requires only 0.19W to actuate the monostable relay. Iskra, 01-668 7141

Snap-action relay. Type R20 is a snap action relay incorporating a microswitch featuring a contact rating of 6A at 250V. The relay has up to three changeover contacts, of either silver-cadmium oxide or 5 micron hard gold-plate. Radiatron Components, 01-891 1221

Solid-state relays. The standard ETA relay is chassis-mounted with TO-3 case centres and has zero-voltage switching. With an opto-isolated input/output of 4kV RMS, these SSRs have a load circuit range of 24-280V RMS and 85A single-cycle peak overload. The control circuit has an input range of 3.5-12V DC and a load-current rating up to 10A. Silicon Power Cube (UK), 0883-717252

Transducers and sensors

Accelerometer. The MGP Series of miniature piezoelectric accelerometers are constructed in stainless steel with electron beam welds to give hermetic sealing of the housing. Threaded studs or holes are provided for fixing purposes. With operating temperature ranges of −55°C to +250°C, the devices have a mounted resonant frequency up to 46kHz. Entran, 0344-778848

COMPUTER

Task-oriented processors

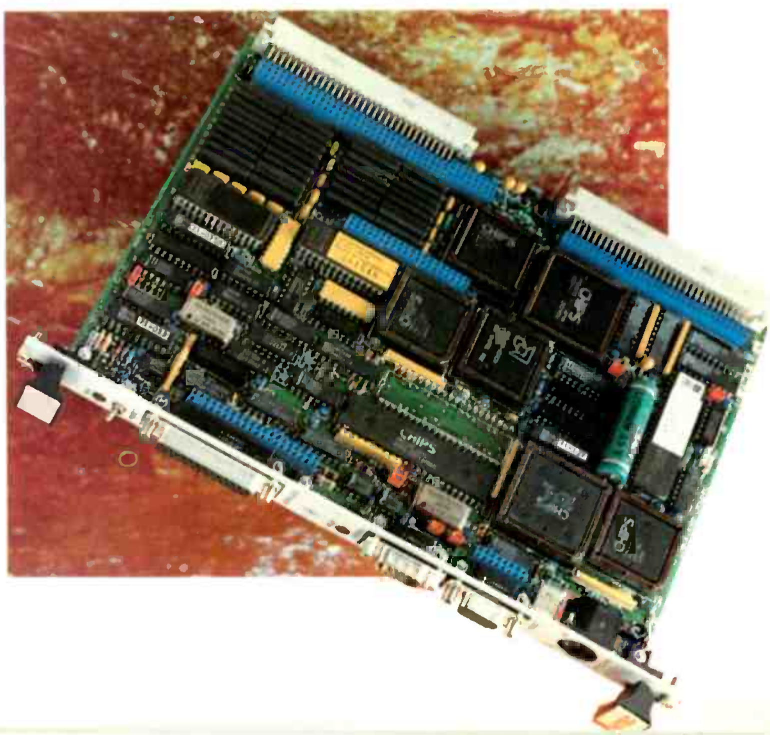
PC module for the VMEbus. The HVME-XT286 allows system designers to run any PC-compatible software on their VMEbus systems. The HVME-XT286 is based on the NEC V30 processor (10MHz clock): this has the same instruction set as the 8086 but is much faster, since all instructions are hard-wired rather than microcoded. HTEC, 0703-58155

High speed FFT analysis. A high-speed solution to fast Fourier transform (FFT) analysis by Plessey Semiconductors consists of three integrated circuits, namely one PDSP16112 (complex multiplier) and two PDSP16316 (complex accumulators). The chip set provide a solution to the Radix 2 Decimation-in-Time (DIT) algorithm for FFT analysis of complex signals, which enables a complex FFT to be broken down into a number of easily calculated two-point Discrete Fourier Transforms called Butterflies. This enables each butterfly to be calculated every 100ns and a 1024 point FFT array in 512μs. RR Electronics, 0234-270272

Computer board level products

STEbus PC. A single-board PC for the STEbus is believed to be the first to provide full hardware and software compatibility while occupying just one backplane slot. The Celeste PC card is based on the 8088 processor running at 10MHz or the V20 at 7.1MHz. Control Universal, 0223-244447

HTEC's HVME-XT286 module for the VMEbus, based on the NEC V30 processor



AI in signal processing

Tom Ivall reports on the knowledge-based techniques for signal processing discussed at a recent IEE Colloquium

To help diagnose abnormalities in the human brain more reliably, Plymouth Polytechnic and Derriford Hospital, Plymouth, are developing a digital signal processing system which is guided by a database of empirical knowledge obtained from medical experts. The brain abnormalities concerned include tumours, epilepsy, injuries and other neurological disorders. These are normally diagnosed by electroencephalography (EEG) but the reliability of the results is often affected by signal artefacts, originating from other parts of the patient's body, which contaminate the EEG signal and make it difficult to analyse. Typical artefacts are the large muscle potentials (in the mV range) resulting from normal eye movements and blinks.

The purpose of the empirical knowledge database is to enable the real-time signal processing to recognise and distinguish between the artefacts and the pathological signals (and between different artefacts) so that it can automatically remove the added artefact components from the EEG signals and produce a 'clean' recording. Clinical information in the knowledge base is held as a series of 'IF. . . .THEN' rules (logical implication statements) built up from years of human experience in the analysis of EEG records. It is utilised as shown in the simplified schematic of the real-time system under development (**Fig.1**).

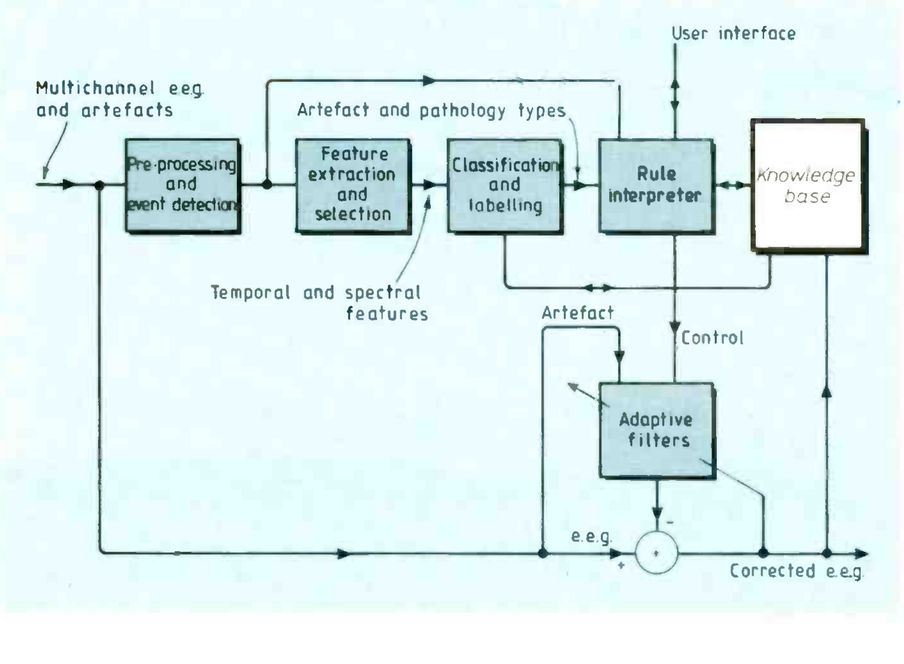
AI TECHNOLOGY

Altogether the IEE colloquium, by concentrating on a specific field of application, proved a valuable corrective to the air of mystery which still surrounds the subject of Artificial Intelligence. As the concept of human intelligence is in itself highly controversial (is it innate or something that can be learned?) the qualifying adjective 'artificial' seems to make this area of both science and technology even more remote. But experience as a technical reporter and editor has taught to me to be distrustful of mere words and their implied concepts, and especially to watch out for what the philosopher A.N. Whitehead calls the fallacy of misplaced concreteness.

As far as electronic engineering is concerned, I would recommend that we forget the word 'intelligence' here and just use the abbreviation AI for convenience (except in farming contexts). AI is effectively demystified if you think of it merely as the latest and most advanced manifestation of non-numerical computing or symbolic information processing. This purely technological function can be conveniently kept separate from the scientific role of AI which, along with psychology, linguistics and philosophy, is really part of the study of human and animal intelligence, now called cognitive science.

After pre-processing, the EEG and artefact signals are passed to a feature extractor and selector, which provides information necessary for determining the regions of signal contamination. These features are classified and labelled and then transferred into a rule interpreter, which, together with the knowledge base, is the heart of the whole system. The rule interpreter produces control rules of the IF. . . . THEN type and these direct the action of the artefact removal process, which takes place in the block marked 'adaptive filters'.

Fig.1. Use of a knowledge base in a system for automatically removing interfering artefacts from electroencephalography signals.



This adaptive-filter artefact removal technique has already been fully developed and used experimentally on its own. Here the information in the contaminated EEG and the artefact signal is used to obtain an estimate of the artefact. The artefact estimate is then subtracted from the contaminated EEG to yield an estimate of the true EEG. As indicated by the variable-control arrow, the true EEG estimate is used to adjust the coefficients of the adaptive filters, by means of a recursive least-squares algorithm, to obtain an optimal estimate of the artefact.

Although this artefact removal filter does work, it suffers from a number of deficiencies as an independent unit. These include non-stationarity and lack of correlation in the signals and the presence of multiple artefacts from different eye movements. It is for this reason that the knowledge-based processing system is being added to distinguish reliably between the artefacts and the pathological EEG signals.

Another knowledge-based, real-time signal processing system is being developed in the UK for the analysis of marine radar signals. The Admiralty Research Establishment (ARE) is supporting research into DSP techniques for automatic detection, surveillance and identification of radar transmitters. It involves receiving on one antenna a multiplicity of radar signals from different sources (total pulse density about 1 million per second), separating them out and identifying them.

One of the problems which makes a knowledge base of human expertise necessary is that the separation process – called de-interleaving – chops up the individual radar pulse trains into fragments. So before the transmissions can be identified these fragments have to be put together again into continuous pulse trains – a technique called merge processing.

It has been found that a merging process based on empirical knowledge gives much better results than a conventional algorithmic approach. This human knowledge is in the form of rules and comes from two main sources: generic information about radar transmissions; and knowledge of the experienced failure patterns of the de-interleaver. The latest position here is that ARE has commissioned Cambridge Consultants to investigate a rule-based merging system working in real time on transputer architecture. Other ARE signal processing research going on concurrently is concerned with rule-based de-interleaving in real time (with Philips) and knowledge-based radar transmitter identification (with SD/Scicon).

Both of these knowledge-based signal processing applications were outlined in a recent IEE colloquium entitled "The application of artificial intelligence techniques to signal processing". E.C. Ifeachor spoke for Plymouth Polytechnic and J. Roe for ARE. Initiated by the colloquium chairman, P.V. Coates of Thorn-EMI Electronics, the meeting was intended to be an informal exploration of the extent to which knowledge databases could be used to advantage in signal processing.

Other fields of application mentioned during the colloquium included speech recognition (using lexical, syntactical and semantic knowledge bases), image recognition, aerial photography, sonar systems, aircraft detection, geomagnetic data analysis, detection and classification of fetal heart sounds, and the accurate re-positioning of patients on nuclear magnetic resonance imaging machines. Some of these were on-line systems, others off-line.

COUPLED SYSTEMS

It seems clear from the above examples that the main reason for using knowledge bases to enhance conventional signal processing is to cope with raw data from the messy real world which is somehow inadequate – erratic, incomplete, unpredictable, contaminated with unwanted data and so on. The input of empirical human knowledge controls or assists a signal-processing system which would otherwise be unable to produce satisfactory results through deterministic algorithms based on conventional mathematical models, because such models often prove inadequate in trying to represent some characteristic of the real world.

An overview paper given at the colloquium by David Sharman of consulting engineers Yard Ltd, Glasgow, put this anecdotal evidence into formal terms with the aid of a diagram like **Fig.2.** It shows the emergence of what are being called coupled systems. These systems are created by interactively coupling conventional numerical computing, based on mathematical models, with symbolic computing, based on coded representations of knowledge, manipulation of symbols, logic and inference. (The well known expert systems typically use an 'inference engine'.

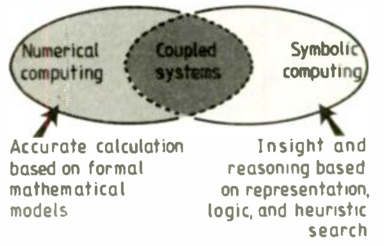


Fig.2. Coupled systems use symbolic processing to control the application of numerical processing efficiently, in accordance with human knowledge previously acquired from experience.

The coupled system, explained Sharman, deals with the kind of problems mentioned above by using symbolic rule-based computing processes to control the application of numerical algorithms. There are two main benefits. First, the coupled system improves the quality of numerically computed solutions. Secondly, it can make savings in the cost and complexity of the computational resources needed by numerical processes.

One way of achieving these savings, mentioned by other speakers as well, is to design the coupled system to selectively direct the numerical processes onto relevant segments of the incoming data or signals, where they will be most useful. This avoids the need to process the entire data or signal. The appropriate segments of data/signal can be selected either by using some characteristic of the incoming information ('data driven') or from expectations of the incoming information derived from a mathematical model ('model driven'). Such 'focus of attention' methods had been successfully applied to image and sonar signal processing, said Sharman.

Judging from the contributions to the colloquium, there seem to be two main methods by which human knowledge is introduced to control the signal processing. One amounts to the interactive coupling of an on-line expert system to the signal-processing equipment. Expert systems are now commercially available in 'shell' form from software houses. But extracting the detailed knowledge from the experts and structuring it into coded forms suitable for symbolic processing is by no means a straightforward task, everyone agreed. In the second method the empirical knowledge is applied not as accumulated expertise but as desired results in specific examples, which provide goals for machine learning systems to aim at.

NEURAL NETWORKS

One form of learning system, which learns by being 'trained' to achieve a specific result, is the artificial neural network. Nigel Allinson, of the University of York, explained that an artificial neural network is an interconnected structure of many simple non-linear processing elements, roughly comparable with biological neurons. The network is trained to learn, from the presentation of examples, to form an internal representation of a problem. The processing elements are often analogue in operation (the Perceptron of 1959 was an early form). Networks can have multiple layers of elements, the layers signifying different levels of abstraction in the representation of the problem.

In signal-processing applications, said Allinson, a neural network can be considered as an adaptive pattern classifier. An unknown input pattern applied to it (e.g. through transducers) is allocated to the most representative of a number of classes. In the training mode the network adapts itself in response to the applied signals by changing the weighting of the synaptic inputs to the processing elements (analogous to the synapses in neurons). After this learning process the synaptic weights are frozen and no further adaptation takes place.

The colloquium did not produce any specific descriptions of neural networks applied to signal processing. Various speakers, however, did mention in passing that these networks were being successfully developed for speech and image recognition, for identifying pulsations in geomagnetic data and for detecting trading patterns in stock market prices. Japan and the USA were the leaders in this field. Sometimes neural-network solutions were attempted when conventional signal-processing techniques would be far better.

Whereas neural networks are essentially non-linear systems – the elements have thresholds and 'fire' like biological neurons – another kind of adaptive device capable of learning, the adaptive combiner, is linear in operation. As described by A.R. Mirzai of the University of Edinburgh, the combiner gives an output which is a linear function of several inputs, the individual effects of which can be varied by weighting. Like the neural network, the combiner can be trained. This is done by presenting to it a set of input values and the corresponding desired output value. An adaptive algorithm then automatically adjusts the weightings of the several inputs to the combiner so that the mean square of the error between the actual output value and the desired output value is brought to a minimum. In practice, multiple adaptive combiners are used in networks because usually more than one output is required.

Mr Mirzai said that this technique had been used in a machine learning system for fault diagnosis and adjustment of electronic devices (e.g. tuning waveguide filters). Essentially it was capable of learning the relationships between the inputs and outputs of a system by looking at a number of examples which included system features and the corresponding desired action taken. (See 'Intelligent techniques for electronic component and system alignment', *Electronics & Communication Engineering Journal*, IEE, Jan/Feb, 1989). The EEG signal-processing application mentioned earlier also uses this general principle, in its adaptive filters. ■

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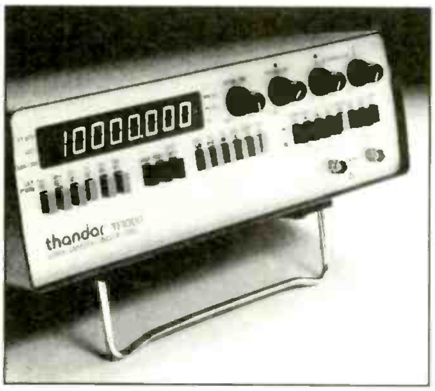

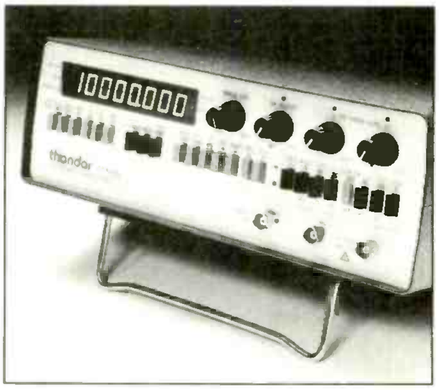

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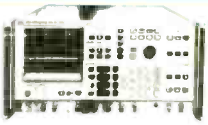

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CIRCUIT IDEAS

Intro scan for compact-disc players

When selecting tracks for programming into a compact disc player, using the track search button can be tiresome. This design, when fitted to any player with a subcode output, allows a scan of the first ten seconds or so of each track.

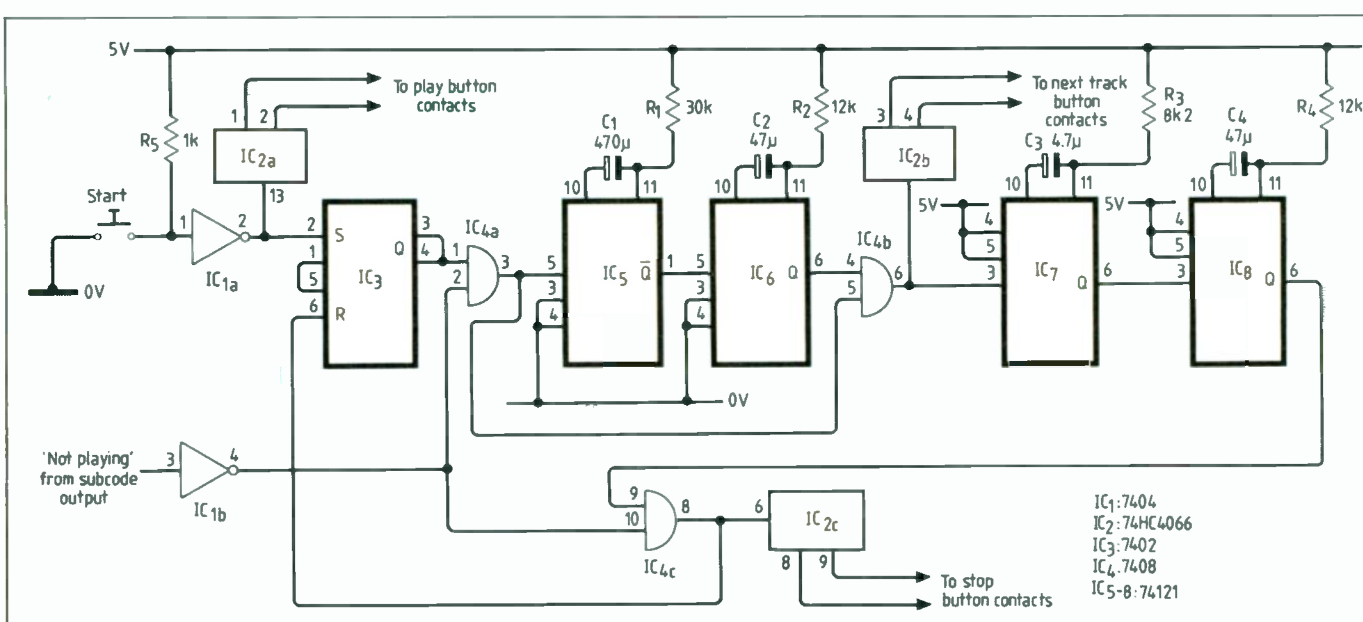
Pressing the start button causes IC_{1a} to go high and operate the play button via IC_{2a}. During the scan, IC_3 latches high. When IC_{1b} goes high as a result of the first track being located, IC_5 produces a low-going pulse of around 10s depending on the RC time constant. Monostable device IC_6, triggered by the rising edge of this low pulse, creates a 400ms pulse which is long enough to trigger the next-track button but not so long as to start any auto-repeat facility that may be built into the player.

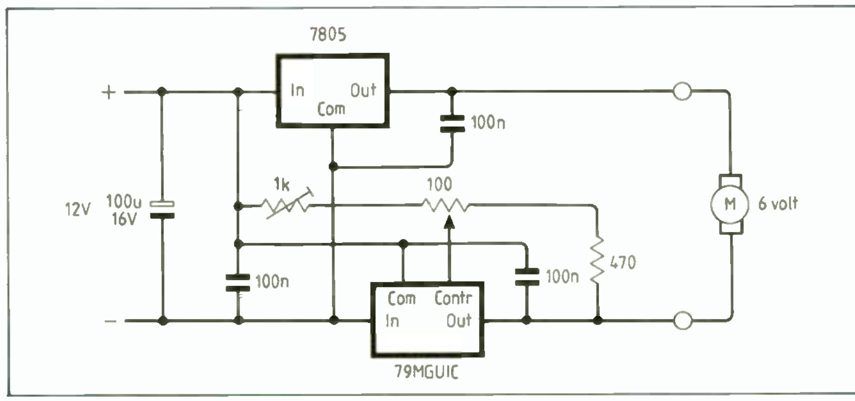
Once the next-track button has been operated, IC_{1b} will go low while the next track is located. On returning high, this IC retriggers the timer.

When IC_{4b} pulses high, IC_7 is triggered. This creates a 30ms pulse which is longer than the time taken for IC_{1b} to go low after the next-track button is operated. The end of this pulse triggers triggers IC_8, creating another 400ms pulse. If at the start of this pulse IC_{1b} is still high, i.e., the disc is still playing because the next-track button failed to find another track, as would be the case at the end of the disc, IC_4 will pulse high for 400ms, operating the stop button and resetting IC_3.

I have tested the design on a Pioneer PD5010 unit, obtaining the 'not-playing' signal from pin 1 of the subcode output socket.

G.J. Aspland
Bury St Edmunds
Suffolk





Motor control

Adjustable voltage regulators make very good motor speed controllers but devices such as the LM317 cannot give an output lower than about 1.35V. In my application, motor voltage had to go to zero and control at low speeds had to be good. This circuit is my solution.

One side of the motor connects to a 5V rail produced by a 7805 fixed-voltage regulator. The 79MG is a four-terminal negative regulator with a separate control terminal. It gives an output from −5V to −12V, resulting in a voltage over the motor from zero to about 7V. Since the 7805 produces 5V at all times, output of the 79MG cannot be reduced below −5V.

Zero motor voltage is set using the 1kΩ potentiometer. The tab of the 79MG is connected to the input pin, which is also ground, so both ICs can be bolted to the same heat sink without insulating washers.

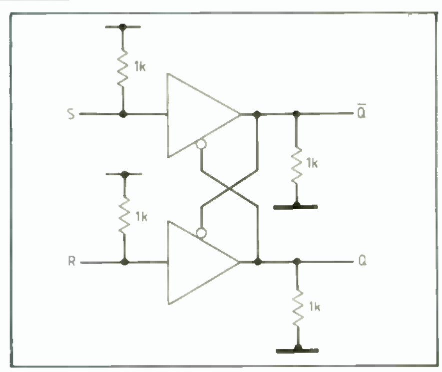
I.W. Berry
Manchester

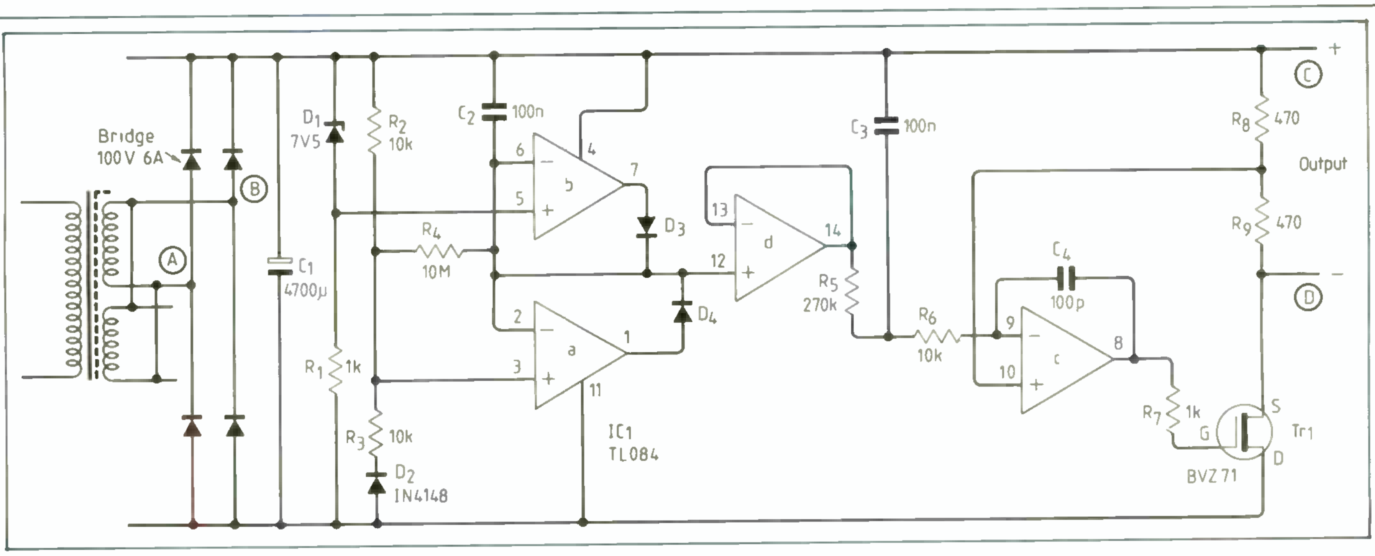
Novel RS bistable

Two spare non-inverting gates from a tri-state IC such as the 74125 can be connected to form an RS bistable multivibrator.

Assume that Q is high. The upper gate is high impedance so its output resistor pulls $\bar{Q}$ low. A negative pulse at R makes Q go low, enabling the upper gate. When the upper gate's output goes high, the lower gate is disabled and thus Q is pulled low.

P.M. Delaney
Wargrave, Berkshire





Low dissipation supply

I needed to power some car audio equipment from a poor 240V AC supply in a yacht. Tests showed that the equipment drew up to 2.5A and that it would not tolerate much 100Hz ripple; it would however tolerate supply voltage variations.

Air flow in the equipment's location was restricted so the supply had to be efficient. Conventional low drop-out voltage regulators waste power; this design is more efficient since it absorbs peaks in the rectifier output while dropping very little voltage during the troughs. As a result, the series-pass element dissipates only a fraction of the power that it would in a conventional linear regulator.

Even though the equipment could handle voltage variations I decided to limit the circuit's maximum output voltage to make its use safe under low load and high input voltage conditions. The circuit is 'upside down' simply because this configuration allows an n-channel power fet to be used instead of a more expensive p-channel device.

Diode D_2 ensures that the input sample from divider $R_{2,3}$ is slightly less than half the input voltage. Precision rectifier IC_{1a} tracks the lowest (most positive) point in the rectifier trough while R_1 provides a slow 'leak' so that if load is removed output from the rectifier will creep up to the new trough value over a second or so.

An upper limit of 15V is placed on the output by R_1, D_1, IC_{1b} and D_3 which ensure that output from the precision rectifier never exceeds 7.5V. Buffered output from the precision rectifier is compared with half the output voltage by IC_{1c}. Residual ripple from the precision rectifier's output is filtered by R_5 and C_3. Resistor R_6 and C_4 slug the feedback loop to ensure stability while retaining adequately fast load response.

Conveniently, the threshold voltage of the power fet ensures that the output of IC_{1c} operates at approximately half the supply voltage. Diode D_2 ensures that the fet always has a voltage across it. Since the BUZ71 has an on-resistance of about 1Ω, the fet will have to drop about 0.25V for the rated output.

Sufficient heatsinking for the prototype was provided by the walls of the small diecast box that the unit was built into. With careful PCB layout, output ripple was visible but unmeasurable on a 5mV/div oscilloscope even with an input ripple of several volts.

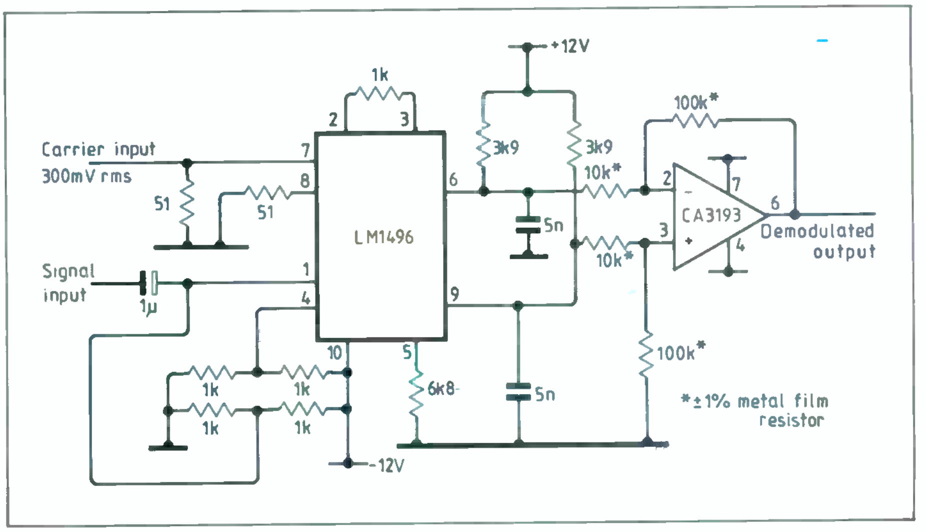
C.G. Miller
Sevenoaks
Kent

Reducing demodulator distortion

Output of the 1496 balanced modulator/demodulator is proportional to the product of an input voltage and a carrier. Suppression of the 1496 output is quite poor at the higher end of its frequency range, and alias frequencies (even multiple of f_c + even multiple of f_s) cause serious in-band spurious interference.

By placing a differential amplifier at the output of the product detector, these unwanted frequencies can be eliminated. Since I only needed low-frequency operation I used a CA3193 op-amp which is pin compatible with the 741 but has more suitable characteristics for this application.

Connecting a balanced amplifier at the output removes the need for a symmetrical carrier to reduce aliasing and it makes highly symmetrical switching in the mixer unnecessary.



Attenuation of $2f_c+2f_s$ products is greater than 60dB. As shown, the circuit is suitable only for low frequencies but if the op-amp is replaced by a CA3450 for example, bandwidth is greatly increased; note that the 3450 and 1496 in this case would both be powered from ±6V rails. The 1496 operates at up to 100MHz.

V. Lakshminarayanan
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India

Tunable loudness control

Here, a capacitance multiplier provides a loudness control that can be tuned with ease to suit the ear. Being easily tunable, it lends itself to experimentation.

At low volume levels (i.e. $n \leq 1/2$, see panel) combined impedance of C_1 in parallel with $R_1/2$ decreases as frequency increases so upper frequencies are boosted. Likewise, equivalent capacitance C_2 produced by the multiplier combines with R_2 to boost lower frequencies.

With R_1 at about 40kΩ and C_1 at about 3nF, tuning the capacitance multiplier and adjusting R_2 achieves a wide variety of loudness effects with simplicity and smoothness (see curves). Resistor R_a tunes the capacitance multiplier; varying it from 0 to 100kΩ varies the corresponding equivalent capacitance of C_2 from 15nF to 1.5μF.

Moving the wiper of R_1 for different volume levels (i.e. different values of n) only shifts the whole compensation curve up or down when all other component values are fixed.

Tseng C. Liao
Peking University
Beijing

LOUDNESS CONTROL TRANSFER FUNCTION

Equivalent capacitance of the multiplier is $C_2 = C_f(1+R_a/R_b)$.

Voltage transfer of the circuit in decibels is

$V_o/V_i = 20\log[nR_1(A^2+B^2)^{1/2}(C^2+D^2)^{1/2}]$

where

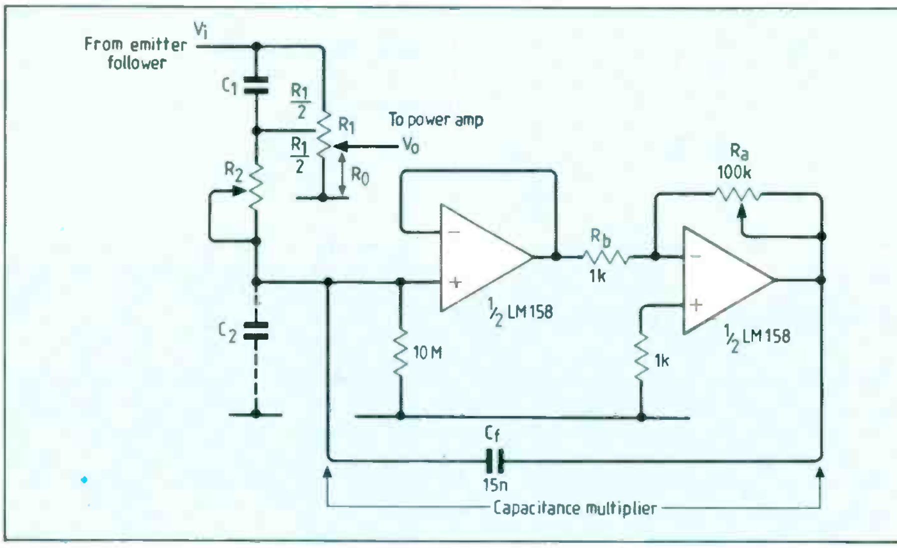
$A = (R_1/2)R_2 \cdot 1/(4\pi^2 f^2 C_1 C_2)$,

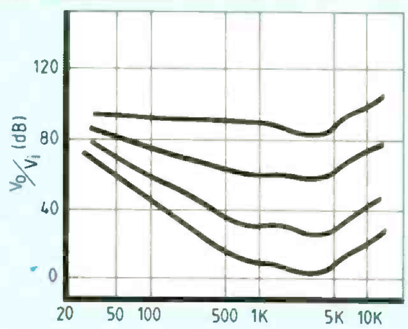
$B = (R_1/2)/(2\pi f C_2) + R_2/(2\pi f C_1)$,

$C = (R_1/2)^2 R_2 - (R_1/2)/(2\pi^2 f^2 C_1 C_2)$,

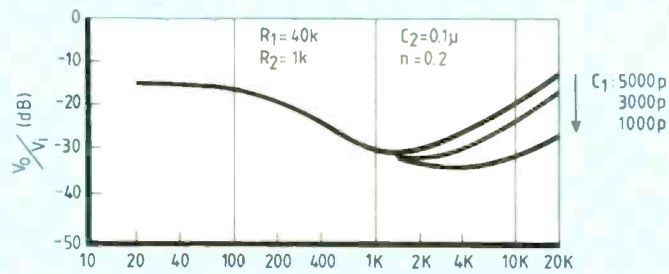
$D = (R_1/2)R_2/(\pi f C_1) + (R_1/2)^2(C_1+C_2)/(2\pi f C_1 C_2)$,

$n = R_0/R_1$.

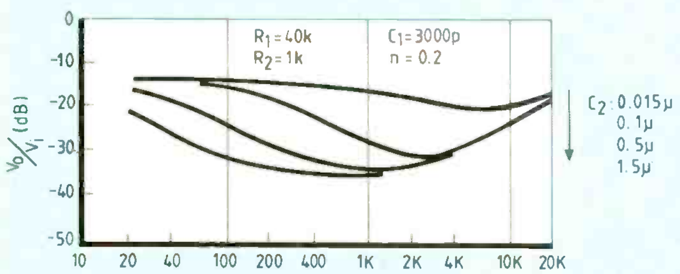




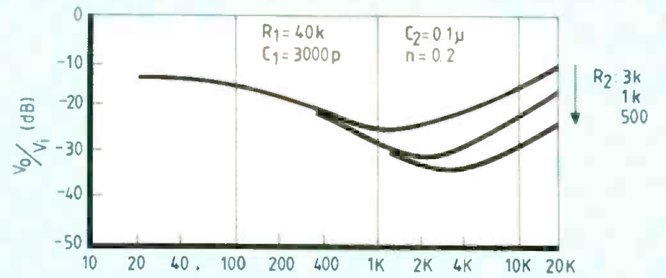
Fletcher Munson loudness curves



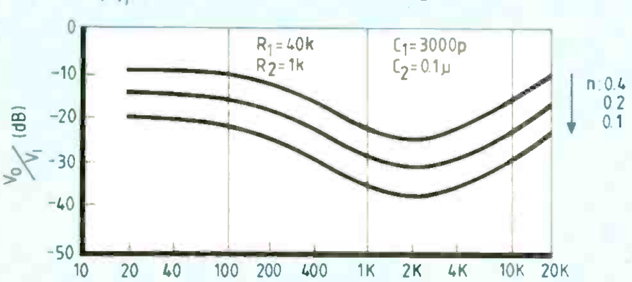
a. V_o/V_i – f curves for different values of C_1



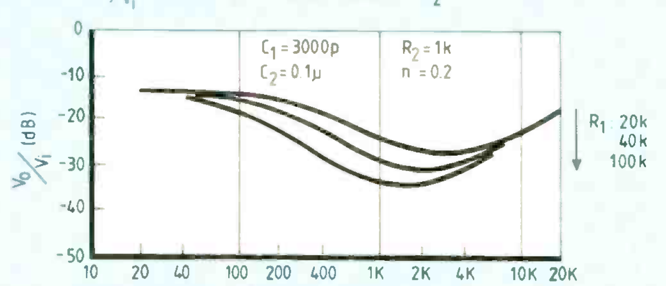
b. V_o/V_i – f curves for different values of C_2



c. V_o/V_i – f curves for different values of R_2



d. V_o/V_i – f curves for different values of n



e. V_o/V_i – f curves for different values of R_1

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ENTER 11 ON REPLY CARD

DIY PLD

In the second part of this article, the author introduces a popular PLD and shows how it can be used to replace blocks of conventional logic.

BRIAN J. FROST

The architecture I described last month is found in many pal devices. But there is one device that has become an industry standard in its architecture and pin capacity – the 16L8. As with eprom type numbers (e.g. 2764), the part number conveys some idea of how the device is actually organized, with pals having numbering of the form

<qty array inputs> <output state logic> <qty array outputs>

for example, 16L8, 20L10, 16R8 etc.

Thus the 16L8 has 16 pins that can be inputs, eight pins that can be outputs, and has logic that organizes outputs toward being low when "active". As we shall see shortly, the active-low description is not as rigid as in the case of outputs taken from, say, a 74LS138 active-low decoder. This is because the 16L8 can be programmed in such a way that the required input condition causes the output to go high.

Figure 6 shows a complete layout of the 16L8 pal allowing us to identify its important characteristics.

In Fig.5, where the address decoder design was coded on to the pal architecture, the 16L8's inputs enter from the left and are available to the entire array in both "true" and "complement" forms by means of pairs of vertical wires. For example the input pin 2 is assigned to vertical wires 0 and 1, the input pin 3 is assigned to wires 4 and 5 and so on.

Each output is the (active low) output of a seven-input Or-gate with each of these seven inputs being a 32-input And-gate that straddles all the vertical wires. Additionally in the case of the six output pins 13 to 18, the state of the output pin itself is taken back into the array and accounts for the remaining vertical wires. This organization means that any output can be made dependent not just on any input combination, but also on the state of any output pin. In situations such as address decoding where there may be very few outputs but a large number of inputs, this feature can be exploited to make output pins 13 to 18 available as "extra" inputs in addition to the dedicated 10 input pins (the 10+6 inputs result in the "16" of the device's name). Since an output can be made dependent upon itself, this feedback facility will be seen to be particularly useful when we move on to the creation of latch functions.

Since any given output may be required to become true on more than just one combination of And-ed inputs, each output is provided with seven such And lines – called "product terms" (Ors) – which are Ored together. (In the simple example of the address decoder, there was only one product term; hence only one And line in Fig.5 was needed for each output pin.)

Another feature of the 16L8 is that each output pin is actually formed using a three-state driver, with its three-state control taken from another single horizontal And wire with one product term. This feature may be used to create an "open collector" type output, or to create a bi-directional pin for applications involving processor buses or other shared-output situations where one or more device outputs can be deselected by combinations of input control lines.

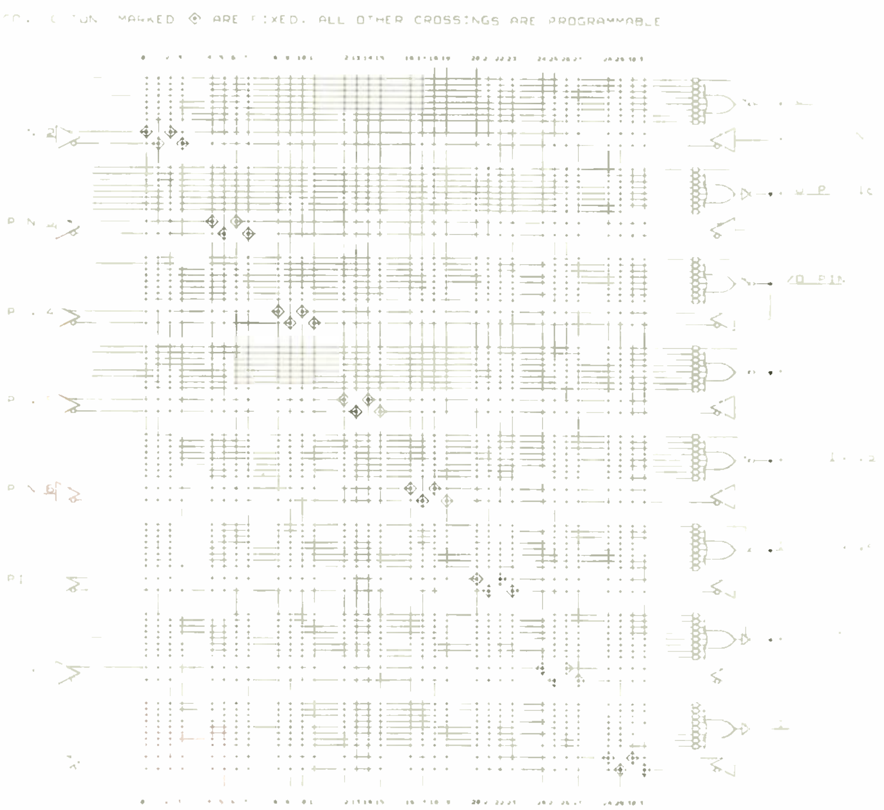


Fig.6. Architecture of the popular 16L8 pal device.

WHERE TO USE THE 16L8

The 16L8 pal is now a very popular PLD and is probably the best value for money: a unit costs 80p-£1.80 depending on quantity. As a result it is a good device on which to learn, since most other devices have a very similar array layout but changed pin quantities and characteristics.

The 16L8 can be programmed to operate as an address decoder, multiplexer, demultiplexer, comparator, or to replace most combinatorial logic functions, i.e. those that do not require clocked or counting operations. In this sense, the 16L8 can be thought of as a collection of universal multi-input gates available to replace or augment such existing TTL circuitry.

A common query expressed by those starting to use programmable logic is how to know in advance whether the particular device is going to fit the application, or whether you will run out of input and/or output pins. Fortunately, no matter which of these limitations – if any – appear during the design, there are several options providing solutions.

A check on the required number of input and output pins is the first task since outputs tend to go quickly. If the number of pins is adequate, the design will fit within a 16L8 if the logic equations can be reduced to fit the seven product terms available on each output.

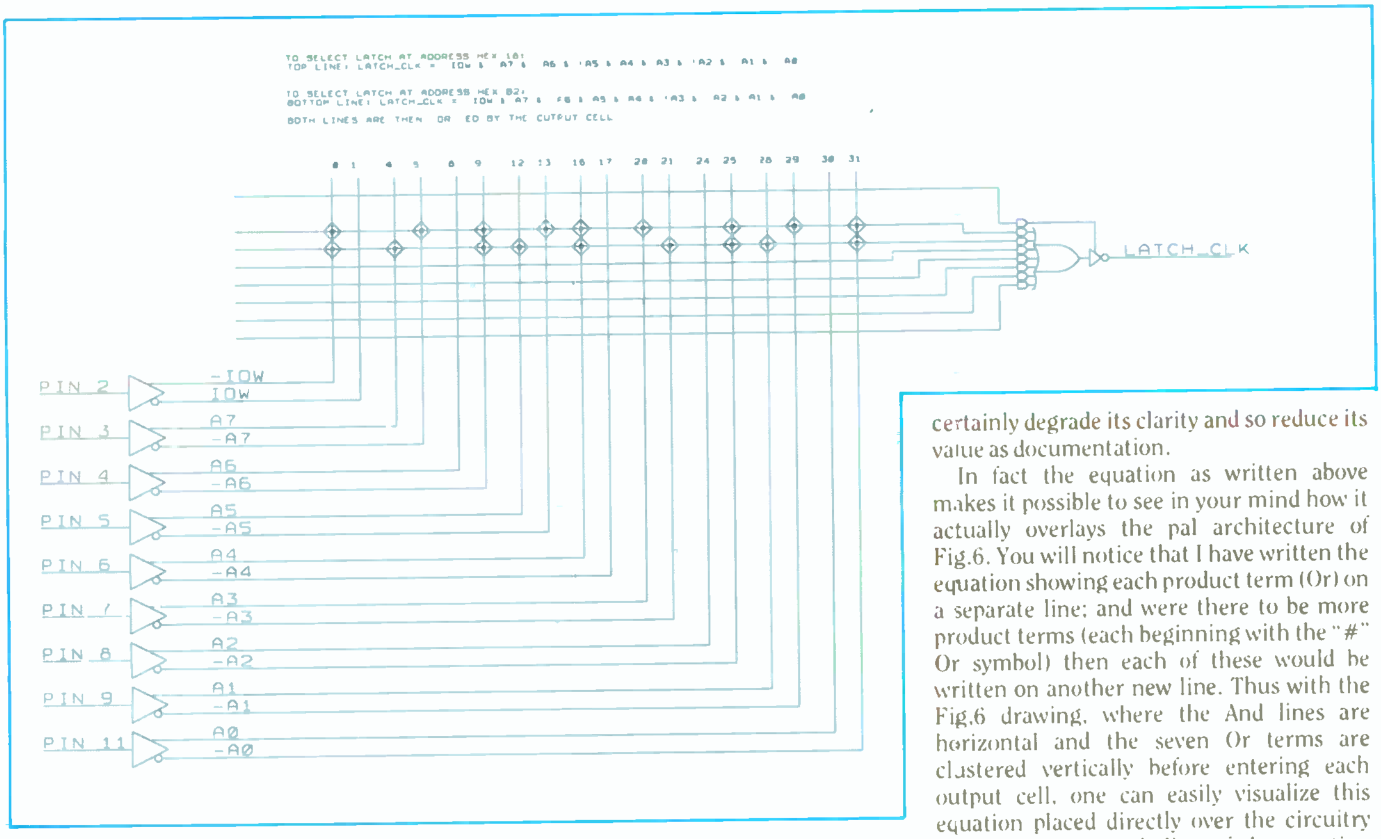


Fig.7. How your equations overlay the pal fuses.

If it turns out that the equation for an output is particularly complex, you always have the option to cascade inputs and outputs by using the feedback path that connects an output back into the array – i.e. a spare output can be thrown away as an internal node within your design. If you do exceed the pin count – and this quite often happens in larger designs – you can either move to a larger device with more pins, or divide your design into smaller sections that would each fit within one smaller pal device. In either case there is no question of having no way out: in fact it is here that the creativity really begins.

In a later section on partitioning your designs we shall look at the trade-offs of these kinds of choices.

WHEN THE 16L8 IS LESS THAN IDEAL

Because of the flexibility of the pal architecture, the same type of array organization has appeared in many subsequent programmable logic devices. Where these differ from the 16L8 is in the output logic cell, which is the logic circuitry associated with each single output pin. In the 16L8 this circuitry is biased towards a pin that is active-low; that is, the minimum number of product terms (Ors) will be used in the array when the pin is used in the active-low state. And since there are 32 And terms but only seven product terms it is possible that using the pin in an active-high mode may exceed the product term capacity of the pin.

An example of this is as follows. Suppose the address decoder example shown earlier were to be modified because the octal latch was required to be selected at two unique addresses that were not successive or related as a power of two. For example the output latch might be required active at address 18_{16} and also at $B2_{16}$.

From the previous design, the equation that selects this latch at address 18_{16} is

```
latch_clk=!IOW&!A7&!A6&!A5&A4&A3
          &A2&!A1&!A0
```

For the additional address $B2_{16}$ the equation simply has its bits altered to correspond to the value B2, e.g.

```
latch_clk=!IOW&A7&!A6&A5&A4&
          !A3&!A2&A1&!A0
```

For the latch to respond to both addresses, these two equations are simply Ored together in exactly the same way as in designing with TTL. Thus a new equation for this would read

```
latch_clk=(!IOW&!A7&!A6&!A5&
          A4&A3&A2&!A1&!A0)
          #(!IOW&A7&!A6&A5&
          A4&!A3&!A2&A1&!A0)
```

where the # symbol signifies the logical Or function.

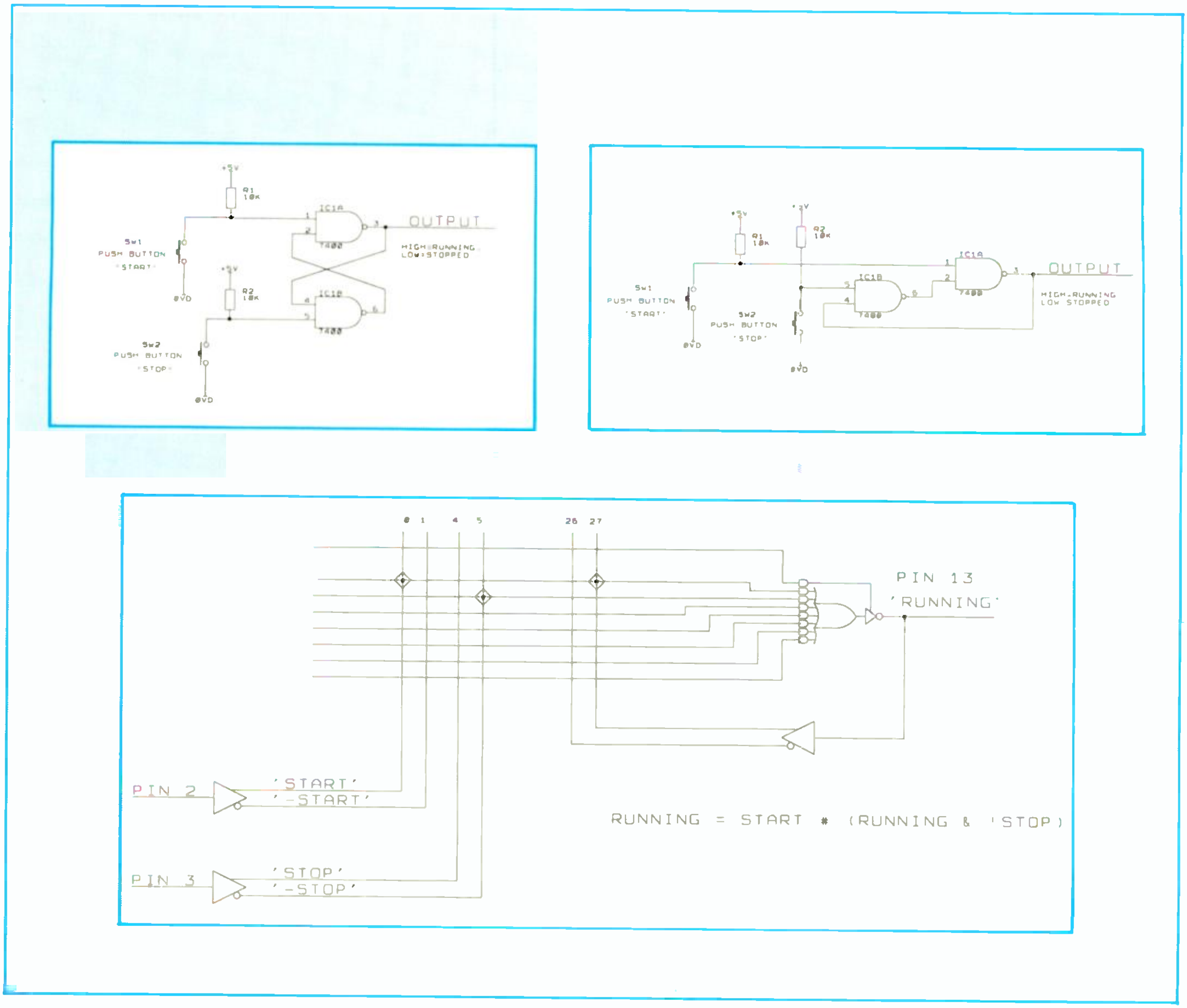
This has created two product terms, one for the address 18_{16}, and the other for the address $B2_{16}$. A point to note is that there is no need to be concerned here with clever reductions of this kind of logic expression down to more compact, but perhaps less comprehensible equations, for two reasons. Firstly, this kind of logic minimization is already handled adequately by the logic compiler that you will use to turn this equation into a fuse map and thus formal knowledge of logic reduction techniques is not required. Secondly, any attempt to reduce the equation manually will almost certainly degrade its clarity and so reduce its value as documentation.

In fact the equation as written above makes it possible to see in your mind how it actually overlays the pal architecture of Fig.6. You will notice that I have written the equation showing each product term (Or) on a separate line; and were there to be more product terms (each beginning with the "#" Or symbol) then each of these would be written on another new line. Thus with the Fig.6 drawing, where the And lines are horizontal and the seven Or terms are clustered vertically before entering each output cell, one can easily visualize this equation placed directly over the circuitry for one output: each line of the equation runs along a horizontal And line and each Or term starts the next horizontal line down.

Figure 7 demonstrates the equation in place in the pal. The drawing has been simplified to remove all but the required output pin (LATCH CLK), and the unwanted output feedback wires have been removed. Associated with this output are the seven horizontal lines, each of which are programmed to And together any combination of the input pins or their inverse. As a result, the upper line has connections shown exactly as specified by reading the equation that selects the output LATCH CLK at address 18_{16}. The next lower line is the same, but constructed for the address $B2_{16}$, and so the output pin becomes 'true' when *either* condition is met.

Notice how close is the resemblance between the fuse pattern and the way the equation is actually written: this makes it easy to see just how much of the pal circuitry for this particular output pin is still unused. For example it is easy to see that across the "width" of the device (in the And direction) one would run out of input pins long before running out of fuses. Thus we could easily add more address lines to our definition, assuming that we still have pins free on the device. By contrast, each time we create a new address at which the output is to be selected, we add one more "product term" to the output and this requires a new horizontal wire. In the 16L8 there are only seven such wires for each output and this becomes a far more real limitation. Running out of available product terms on an output is probably the most common mistake – second only to trying to assign one of the power pins to be a signal!

Now back to logic minimization. As I have mentioned, the 16L8 is organized for outputs that are true when low – hence the inverter symbol on the output cell. However,



this does not prevent us from using the device to generate outputs that are true when high, because the logic compiler will re-arrange the way that the equation is specified to try to fit it within the physical organization of the device. This operation is directly equivalent to that in TTL design where you find yourself with several Nand gates available, but need a Nor function; and you solve the problem by placing Nand inverters on another Nand gate's pins. The great advantage with the pal is that inverters already exist at each input of the pal, and only the And and Or terms of the equations need to rearranged to fit inverted equations.

Compared to the TTL design, we are spared the boolean arithmetic that such logic conversion would entail since the logic compiler will perform this automatically, removing any redundant logic terms. Whilst you might have an initial feeling of a loss of control over the design, you will still see the exact operation of the logic by examining the simulation results, as explained earlier.

Although this logic conversion is an excellent tool for allowing pin polarities to change as required, it is worth bearing in mind is that when you specify an output pin to be used inverted from the way that the pal was organized it can generate more product terms than you expected. For example,

Fig.8. Simple SR latch function (a), redrawn (b), and implemented in a 16L8 (c).

consider the expression

```
output=
  !(in1&in2&in3&in4&in5&in6&in7&in8)
```

This requires that the output is true and low when inputs 1 to 8 are all high (i.e. it is a big Nand gate). Should we want to invert one or more inputs, the way in which the equation fits inside the pal does not change: the input is simply taken into the array inverted using a different fuse link and the same horizontal And wire used.

However, if we needed the output to be true and high (i.e. a big And gate instead), we would write

```
output=
  in1&in2&in3&in4&in5&in6&in7&in8
```

The 16L8 pal is still an active-low device and so the logic compiler will reorganize the expression in such a way that logically it is identical, but physically the output is low when false, i.e.

```
output = !(in1
          #in2
          #in3
          #in4
          #in5
          #in6
          #in7
          #in8)
```

This is still the big And gate function that we wanted; but it now uses only one fuse connection along each horizontal And line in the pal requires eight Or product-term lines to fit. Because there are only seven in the 16L8, this expression has too many product terms to fit.

Of course one could combine this expression with another output to fit it within the 16L8 pal, but the example does illustrate how any particular pal device gets its limitations from both the fuse pattern and the way in which the output cell is oganized. The next step is to examine how other devices use different output cell types to solve specific requirements.

COUNTING AND LATCHING

Although popular, the 16L8 pal is really useful only for general "combinatorial" applications which allow it to replace some of the most untidy gate bits of TTL logic. Generally it cannot perform counting or other clocked operations because these

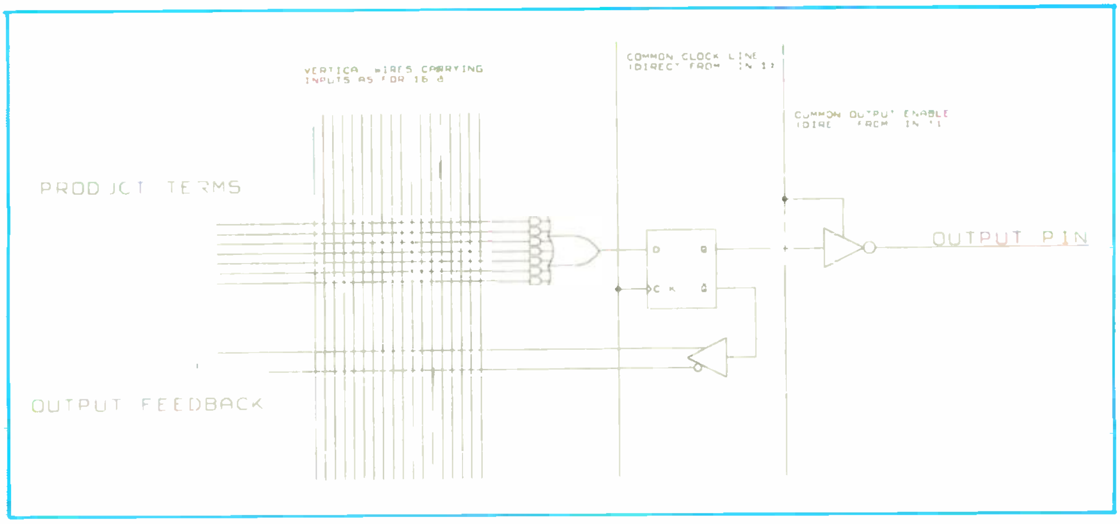


Fig.9. One output of the 16R8 pal.

functions are too complex to implement in the fuse array. The 16L8 can, however, implement the set-reset latch function, often shown as a cross-coupled Nand-gate (**Fig.8a**), and this happens to illustrate how close the correspondence between a gate-based design and its pal equivalent can be.

Many of us have used this type of circuit, where a 7400 gate IC_1 is used to provide a simple latching start/stop control circuit. The start button sets the output high, the stop button resets it low.

Ironically, the best explanation of how this circuit fits into a pal is achieved by changing Fig.8a to a type of drawing that always annoys me if I see it used on a circuit diagram – an identical circuit but drawn with the gates cascaded, so making the essential latch nature much less evident. Now look at Fig.8c, where this same function is coded into a 16L8 using just three fuses.

Activating the start input to the pal makes the output "Running" go true because there is no other And term on its line.

As this output goes true, it latches itself in the true state because its own output is being fed back into the array as another term Anded with the inverted state of the stop input. Thus the Running output continues to hold itself set until the stop input is activated to release the latched output. The signal flow as seen on the pal architecture can be seen to be very like the "cascaded" latch drawing of Fig.8b and the operation of the pal latch is identical even down to the indeterminate output that results from depressing both buttons at the same time!

This is one example of using low-level gating to implement a SR latching function, but to perform more sophisticated counting operations some additional circuitry is required to the basic 16L8 pal. One method of doing this is to insert a flip-flop between the seven-input Or-gate and the output driver, as shown in **Fig.9** where a D-type flip-flop is used, and the pal becomes a repeated array of one of these functions for each output pin. This particular device is named the 16R8, where the R stands for registered. Incidentally, appreciation of these two devices 16L8 and 16R8 gives a newcomer actual knowledge of some 20 real pal devices, since there are relations within the family where the total outputs comprise a mix of registered and direct outputs. This mix is conveyed by the type number: 16R4 contains four registered outputs, the 16R6 contains six registered outputs etc. Other devices follow the same nomenclature but with smaller pin-outs.

In the 16R8 registered pal, the clock inputs to each flip-flop are commoned and brought to one external pin, reflecting the synchronous nature of clocked functions built with this device. In fact as we shall see shortly, the construction of any counter is only one sequence of a general set of sequences possible by a 'state-machine', or programmable sequence generator, where any *next* state can be defined as a function fo the *present* state. Behind this definition lies the key to the design of any clocked functions using PLDs.

The flexibility of the 16R8 in Fig.9 is due to the fact that the D input of its flip-flop can be made dependent upon the state of any combination of the device inputs or its outputs. This means that on any successive clock pulse, all the flip-flops can be set to a new state determined by the states of the device input pins and the flip-flop's last states. For example, it is easy to see that a reset operation can be implemented here by having one input pin (call it "reset") that uses the array gating to present an overriding logic 0 to all D inputs of each flip-flops irrespective of any other gating. With this reset input true, receipt of a clock pulse would cause all flip-flops to move to the 0 (reset) condition, implementing a "synchronous" reset operation.

Because of the various array fuse connections that can precede these D-type flip-flops, it can also be shown that all other types of conventional flip-flops can be created from this D-type design by suitable design equations. ■

In the concluding part of this article, the author will present a simple counter as a design example, and will discuss of software and hardware programming tools.

Further reading

There is much information readily available on the subject of PLDs, most of which explores their application and examples far more comprehensively then this article. Below are listed a few of the more prominent manufacturers and their (often free) data books. To obtain these or other information, contact several semiconductor distributors, since in the interest of promoting these devices they can all provide large quantities of data on request. This list is by no means comprehensive.

Advanced Micro Devices. Use the PAL Device Data Book 1988 and the PAL Device Handbook 1988 for information on pals generally, their design, and using AMD's logic compiler PALASM. There are many examples and problems with their solutions. Use the PGA Data Book 1988 for information specific to the Logic Cell Array device.

National Semiconductor. Use the Programmable Logic Design Guide for information on all National s devices, a general overview of logic design and many examples.

Texas Instruments. Use the Programmable Logic 1988 Data Book for information on all Texas devices including FPLAs and proms.

Philips (Mullard, Signetics). Use Programmable logic devices (Book 4 part 7a) for information on all Signetics devices and their AMAZE logic compiler.

Altera, Cypress, Lattice. These companies specialize in erasable PLDs.

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PIONEERS

30. Alan Mathison Turing (1912-1954): the solitary genius who wanted to build a brain.

W.A.ATHERTON

Buried treasure conjures up childhood images of sandy beaches, tropical islands and Long John Silver. The M25 London circular motorway hardly fits this image; but next time you are stuck in a traffic jam, spare a thought for buried treasure. For somewhere near junction 22, during the dark daysof 1940 when Britain awaited invasion, Alan Turing buried two bars of silver bullion. It seems strange to relate that the man who did as much as anyone to break the German codes, and whom many regard as the father of the modern computer, was unable to find his hoard again.

A long-distance runner and cyclist, Turing has been described as a self-reliant misfit who ran against the social norms of his time. He was a practising homosexual at a time when this was not only illegal but was deemed to be a security risk. He paid the price of being found out, if that is the right expression, for Turing was deeply honest to himself and never concealed his homosexuality.

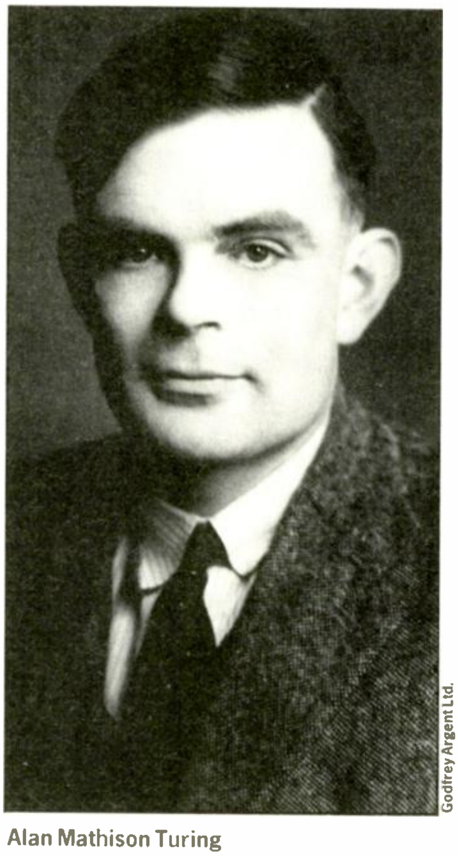
In his trial at Knutsford in 1952 he was described as "a national asset" and "one of the most profound and original mathematical minds of his generation". It was true, but he was still found guilty and was given probation on condition that he accepted hormone treatment – in effect, chemical castration. According to his biographer, Andrew Hodges, Turing rode the storm as if he had been caught doing some naughty experiment in the dormitory[1]. But a little over two years later, on June 7, 1954, he doused an apple with cyanide and killed himself.

Turing's claim to fame is as one of the fathers of electronic computers. His 1936 paper "On Computable Numbers" is the classic in its field. He dreamed of making a "brain", his Universal Machine. His influence was felt by all the early pioneers of computers from von Neumann in the USA to the teams that built the first post-war British computers. The National Physical Laboratory's ACE computer was his concept of a Universal Machine. Today his memorial is The Turing Institute in Glasgow, dedicated to research and training in artificial intelligence.

CHILDHOOD

They say the child is the father of the man and that seems to have been true of Alan Mathison Turing. For long periods he was separated from his parents, especially his father. Later in life he was a confirmed solitary, one with whom many found it difficult to get along.

Turing was born a Londoner, in Paddington, on June 23, 1912. His mother, formerly Ethel Stoney, was a distant relative of George Johnstone Stoney, the Irish physicist who gave the electron its name. Alan's father, John Mathison Turing, served the Empire through the Indian Civil Service. For the first decade of his life Alan and his elder brother, another John, stayed in England whilst their parents lived in India, except for their often long visits to England. Much of the time the boys were farmed out to a retired Army couple at St Leonards on Sea near Brighton.



Alan Mathison Turing

Alan Turing has been described as a naughty, wilful and cheeky boy[1]. Apart from being par for most boys it may also have been an outworking of his high intelligence, which was recognized quite early. Once on a family holiday in Scotland he noted the flight paths taken by bees, plotted the intersection and bravely raided the nest for honey. He was also said to be a jolly boy and to have a high integrity to which he held strictly in adulthood. Confidences were rigidly respected. There may have been a hint of his future mathematical abilities in his habit at one time of stopping at every lamp post to read the serial number.

Throughout his life he appears to have been untidy. As a child, he found writing difficult and accompanied it with many ink little about his personal appearance. Colleagues remember the holes in his jacket, the old tie he used as a belt, and the bright red cord that served as a pair of braces long after the day when his real braces broke.

When Alan was about 12 years old his father resigned from the Indian Civil Service and settled for an early retirement in France, at Dinard in Brittany. School French lessons suddenly acquired a purpose. So far he had been educated by his mother, at a private day school, and then at a preparatory school near Tunbridge Wells. He was particularly interested in maps and formulae.

For public school it was decided that he should go to Sherborne in Dorset. When he arrived at Southampton from France in 1926 there were no trains because of the General Strike. He set out on his bicycle and arrived on the second day. Later in life he rejected an offer of an official car in favour of his bike. Cycling and running were to be his great loves. He learned to run, so he said, by avoiding the ball on the hockey pitch. But for an injury, he might have qualified for the British marathon team in the 1948 Olympic Games: his best time was only 17 minutes behind the Olympic champion[1].

At Sherborne his ability at mathematics developed, as did his passion for science. He took an avid interest in astronomy to which he was introduced by a fellow student with whom he developed an intense, but doomed, friendship. Tuberculosis killed his friend in 1930. But Sherborne fulfilled its purpose and in 1931 he progressed to King's College, Cambridge – Britain's Mecca for a mathematician. Turing gained his degree in mathematics with distinction in 1934 and was awarded a research studentship of £200. This was followed in 1935, at the tender age of 22, by a coveted Fellowship at £300. At last he had the academic freedom to pursue his ideas.

COMPUTABLE NUMBERS

Almost simultaneous with his election to a Fellowship was the publication of his first paper, a slight improvement on earlier work by the master mathematician John von Neumann. As it happened, von Neumann arrived in Cambridge shortly afterwards to spend the summer away from his home university of Princeton in America. Turing almost certainly attended his course of lectures; but his main problem now lay in choosing his field of research.

His interest in mathematical logic had been aroused by M.H.A. Newman's lectures in 1935. These included problems posed at the end of the 19th century by the German mathematician David Hilbert. One of these remained unsolved and in 1928 Hilbert himself proposed the *Entscheidungsproblem* – "to find a method for deciding whether or not a given formula is a logical consequence of some other given formulae". (The mathematical details are discussed in references 1 and 2.)

Turing solved the remaining problem and went on to postulate a logical machine that could solve any problem of logic provided it was given a suitable set of instructions. This ran counter to the prevalent belief that different calculating machines were needed for different mathematical problems. Turing showed that it was possible logically, if not physically, to have one machine to do all. The concept was soon to be known as a "Turing machine". Within ten years such machines had, as Gandy put it, "descended from the sky to the firm ground of information technology"[2].

Turing's paper was called "On Computable Numbers, with an application to the Entscheidungsproblem" – Computable Numbers for short. Alan Turing had solved a major problem of mathematics with a fresh, direct and "simple" approach. Though it would take a little time to establish his reputation, that reputation was now assured.

He was not the only one to tackle the problem, however, for it had just been solved by an established American mathematician, Alonzo Church, at Princeton University. Though Turing's approach was radically different from Church's, the discovery of Church's work must have been a painful experience. Max Newman wrote to Church asking for help in getting Turing to Princeton so that he could be at the centre of things for a time and "so that he should not develop into a confirmed solitary". Alan Turing duly sailed for America on September 23, 1936.

Princeton University had acquired the status of being the place for a mathematician to be. The Institute for Advanced Study had been set up there in 1932 and the double institute, as it could be viewed, attracted leading scientists to its bosom: Einstein was there, for example.

As with many great ideas when they are new, "Computable Numbers" did not cause a sensation though Church's review of it coined the expression "Turing machine". Turing described his work at a poorly-attended seminar and the paper was published whilst he was at Princeton. He was offered a second year in America, accepted, and submitted for a Ph.D. after a brief return to Cambridge.

BLETCHLEY PARK

By the time he received his Ph.D. in June 1938, a number of things had happened which set his course for the next few years. Von Neumann had become aware of, and admired, "Computable Numbers" and had offered him a research assistantship at the Institute of Advanced Study. Turing had built an electronic multiplier and developed his earlier interest in codes and ciphers. And Hitler's war was threatening.

Bravely he turned down von Neumann's offer and returned to Cambridge in the hope that "Hitler will not have invaded England before I come back". He arrived at Southampton on July 18 with his electronic multiplier wrapped in brown paper. Within weeks he was on a course at the Government Code and Cipher School, one of sixty or so people earmarked for recruitment if war should break out. The day after war was declared he reported to Bletchley Park in Buckinghamshire, the home of the Code and Cipher School, and set to work on the German ciphers. He was ideal for the job.

The British effort at breaking the German codes initially depended on work done in Poland. It is a complex story and one that has already been described, for example by Hodges in his biography of Turing[1]. The Germans used a machine called Enigma to encipher their messages but the Poles had, in effect, obtained a logical copy of the basic machine. To break the cipher they had built other machines which, because of the ticking noises they made, came to be known as *bombes*. The Germans increased the complexity of Enigma and rendered the Polish *bombes* ineffective.

He arrived at Southampton with his electronic multiplier wrapped in brown paper...

The Bletchley team, especially Alan Turing and Gordon Welchman, brought new ideas to the problem and new *bombes* were designed and built. According to Hodges they were "impressive and rather beautiful machines, making noises like that of a thousand knitting needles". There began what Hodges has termed the "relay race" as each side sought to stay one step ahead of the other but with the Germans never believing that Enigma had been broken, only that spies were at work[1].

When America came into the war Turing was despatched on the *Queen Elizabeth* to brief them on the cipher breaking work. During his visit he spent a couple of months at Bell Laboratories, meeting Nyquist and Claude Shannon amongst others. Meanwhile Max Newman had arrived at Bletchley and had started work on electronic counting machines which became known as the Robinsons. These were followed by a series of electronic computers, each known as Colossus. Turing played little, if any, part. He moved on to a new pet project on speech encipherment which reduced speech to meaningless white noise and then recovered it. He designed the machine, built it, called it Delilah – and it worked.

By the end of the war Turing had returned to his pre-war ideas, developed now into a Universal Turing Machine. Strengthened by his experiences with electronics he faced the question of whether this could now become something more than an intellectual concept. Could it become a real machine? He wanted to build an electronic "brain", essentially what we would now recognize as an automatic digital computer with internal program storage.

Of course he was now not alone in thinking such thoughts, for in America the ENIAC was now built and plans had been published for another machine to be called EDVAC. Such news probably influenced the National Physical Laboratory in its plan to build a national computer with Turing's help: a Universal Turing Machine. It was to be known as the Automatic Computing Engine or ACE. Turing's design used binary arithmetic and was to have the simplest possible hardware based on the logical functions And, Or and Not, and a large and fast memory. The rest would be performed by the sets of instructions, the programs. As a design it was unique and owed little to the other pioneer computers[3].

Funds were allocated in 1946 to begin work on a small machine, later known a Pilot ACE. Internal politics and delays did not augur well, however, for the urgency of wartime had not carried forward into peace. Turing left before even the Pilot ACE was completed. He was on sabbatical at Cambridge when the new computer team at Manchester University offered him a position. He accepted in May 1948 and joined them in the autumn. The Manchester prototype ran its first program on June 21, 1948, and in February 1951 the first of the Ferranti Mk1 computers was delivered, based on the university machine. Pilot ACE (which is now in the Science Museum, London) ran its first program on May 10, 1950, and the full ACE was not completed until late in 1957[3]. At Manchester, Turing came to spend much of his time in developing programming techniques, even doing manual arithmetic in base 32.

Turing was always a loner. Many found him difficult to get on with. He received the OBE in June 1946 as official thanks for his wartime work. It came through the post. And in March 1951 he was elected a Fellow of the Royal Society, probably a more fitting tribute. Glasgow's Turing Institute opened in 1984. Perhaps one more tribute is yet to come, when someone finds those silver bars near the M25 motorway. ■

References

1. A. Hodges, Alan Turing: The Enigma, Burnett Books, 1983. Much of this article is based on this excellent biography.
2. R. Gandy, A victory against logic, *The Times Higher Education Supplement*, June 19, 1987, p13.
3. S.H. Lavington, Early British Computers, Manchester University Press, 1980.

Next in this series will be Konrad Zuse, the German computer pioneer.

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Microcomputer-controlled audio preamplifier

A new op-amp technique makes it possible to create a remotely controllable preamplifier on a single chip without sacrificing audio quality.

PETER KRÜGER

Until now, the circuits used to control the input selection, gain and frequency response of signals in audio preamplifiers have usually consisted of switches and complicated RC networks with potentiometers to provide control. In these systems, the potentiometers and switches lie in the signal path and are expensive and bulky, and they deteriorate with wear. They have to be connected to the circuitry using screened cables – which are nonetheless affected by spurious signals – and they restrict the freedom of the control panel designer. These limitations have demanded a new approach to satisfy the stringent demands of modern equipment.

One solution was to control op-amps in the signal path, using voltages derived from manually-operated potentiometers. This method eliminates problems caused by potentiometers situated directly in the signal path, but still requires expensive and unreliable electromechanical controls. Multi-gang potentiometers develop tracking errors and become noisy as a result of wear, especially in a harsh operating environment. They are also difficult to adapt to the trend towards computer control, especially if remote control is required.

However, Philips has developed an entirely new approach to audio signal control, using a VLSI circuit under the command of simple pushbuttons. A microcontroller (microprocessor plus rom) connected via a simple, two-wire I²C-bus processes the input commands.

At the core of this VLSI circuit are op-amp stages where the gain is switched according to data on the I²C-bus. Connecting op-amps in series provides a complete control system with independent control for input selection, gain and frequency response.

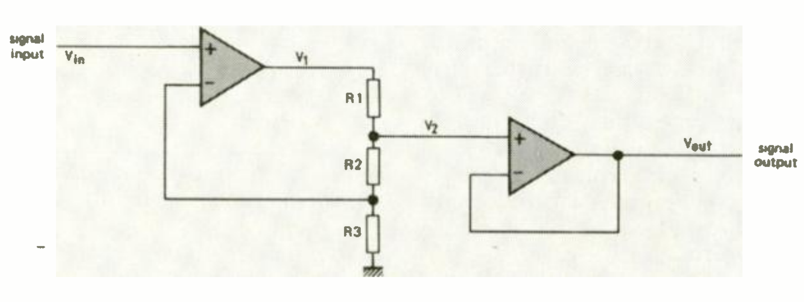
To design a system consisting of several op-amps in series which still achieves high quality performance demanded that special attention be paid to noise, distortion, offset voltages and the suppression of supply line spikes.

LINEAR SIGNAL CONTROL

In the double op-amp stage shown in **Fig.1**, the left-hand, non-inverting op-amp provides an output voltage V_1 depending on resistor values R_1-R_3. The right-hand op-amp is a voltage follower with a potential divider on its input. The output voltage is therefore V_1 multiplied by a fraction determined by resistors R_1-R_3, and the total gain of this stage depends solely on the values of R_2 and R_3. Insertion loss is small because of the infinite input impedance of the left-hand op-amp and the very low output impedance of the right-hand op-amp.

If independently-controlled, four-position switches are introduced at the op-amp inputs, with connections to the resistive potential divider **(Fig.2)**, then the gains of the left-hand and right-hand op-amps can be independently set to one of four values. Total gain of the op-amp stage is again obtained by multiplying the two op-amp gain values, to give, theoretically 4×4 values for the total gain. In fact, there are only 13 values since four of the total gain values are 1 (0dB). Since the left-hand op-amp always provides amplification and the right-hand op-amp always provides attenuation, it is possible to control the output signal level in predetermined steps (e.g. 2dB) by the selecting the resistor values R_1-R_4. To control the output signal level in 2dB steps would require three 6dB steps for the gain of the right-hand op-amp, and three 2dB steps for the gain of the left-hand op-amp, to give an output signal control range from +6dB to −18dB. Naturally, an extended linear signal control range is obtained by cascading stages, so that a linear signal control range of 96dB in 2dB steps is possible using four cascaded linear op-amp stages. Note that although Fig.2 represents the principle involved, it does not show the actual physical switching arrangement.

Fig.1. This dual op-amp stage arrangement illustrates the operating principle of the new device. Total gain depends solely on the resistor values R_2 and R_3.



BASS CONTROL

Adding a single capacitor in the feedback loop of the left-hand linear op-amp stage **(Fig.3)** allows the low-frequency end of the frequency response characteristic to be controlled. The op-amp stage gain now includes a pole and a zero where the break-points of the transfer function are determined by the resistor and capacitor values. At very low frequencies, the capacitor is effectively open-circuit and so the circuit operates as a linear op-amp stage. At high frequencies, the capacitor is a short circuit and sets the op-amp stage gain to unity irrespective of the switch positions. The low-frequency amplification/attenuation is, therefore, determined by the resistor values and its effective range by the resistor and capacitor values. Since the gain control range is determined only by the resistors, the capacitor value is used to set the effective frequency range (example, **Fig.4**).

TREBLE CONTROL

Likewise, adding a single capacitor to the linear op-amp stage **(Fig.5)** makes it possible to control the high-frequency end. At low frequencies, the high reactive impedance of the capacitor reduces the current through R_4 to set the op-amp stage gain to unity independent of the switch positions. At high frequencies, the capacitor is virtually a short circuit so that the circuit operates as a linear op-amp stage. High-frequency amplification/attenuation is determined by the resistor values only, and the frequency range by the breakpoints established by the resistor and capacitor values. For this reason, the capacitor value is used to set the effective frequency range (example, **Fig.6**).

When the op-amp stage for controlling either low or high-frequency response is switched so that the left-hand op-amp is in position 4, and the right-hand op-amp

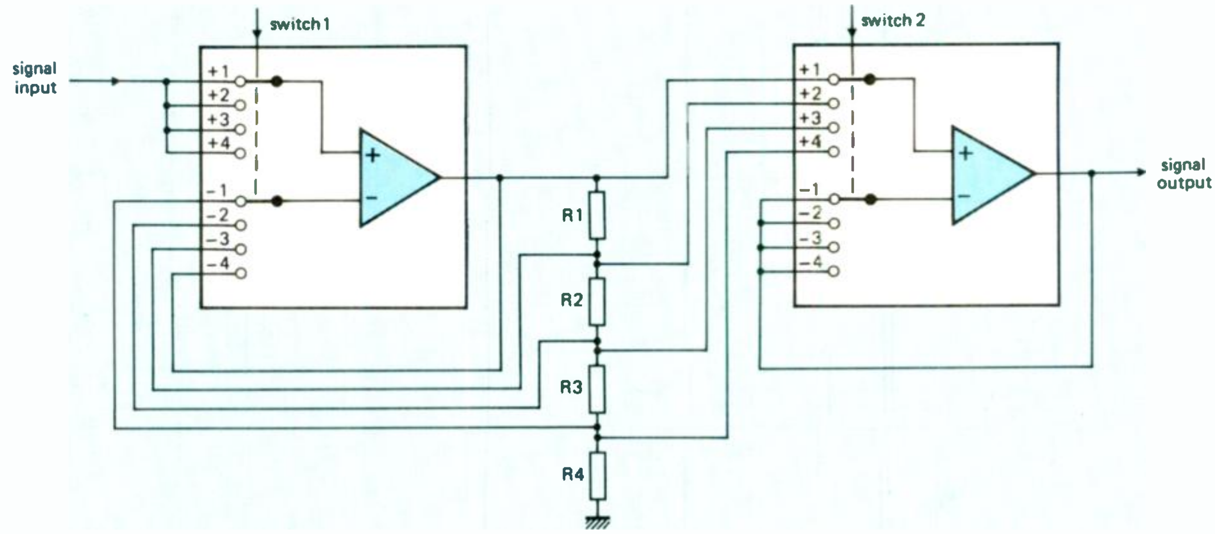


Fig.2. If independently-controlled, four-position switches are introduced at the op-amp inputs, the gains of the left-hand and right-hand op-amps can be independently set to one of four values.

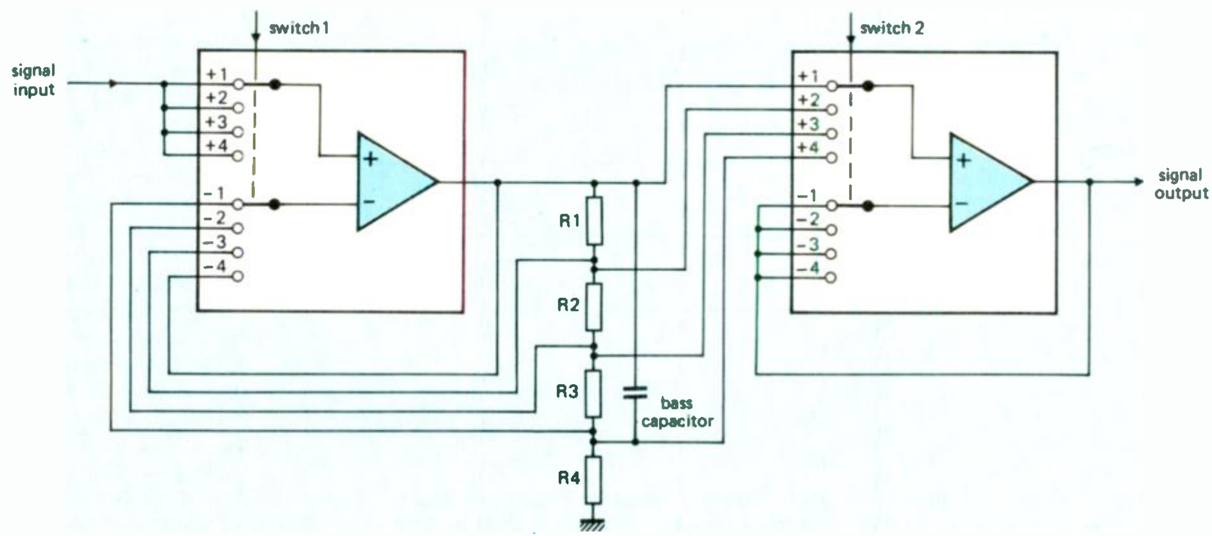


Fig.3. Inserting a single capacitor in the feedback loop of the left-hand op-amp stage makes it possible to control the low-frequencies. Low-frequency gain is determined by the resistors and the effective frequency range by the resistor and capacitor values.

is in position 1, both op-amps operate as frequency-independent source followers. This has the advantage that above approximately 300Hz the gain is unity and independent of component tolerances. It can also be seen from these curves that the incremental gain at a given frequency is the same for each step.

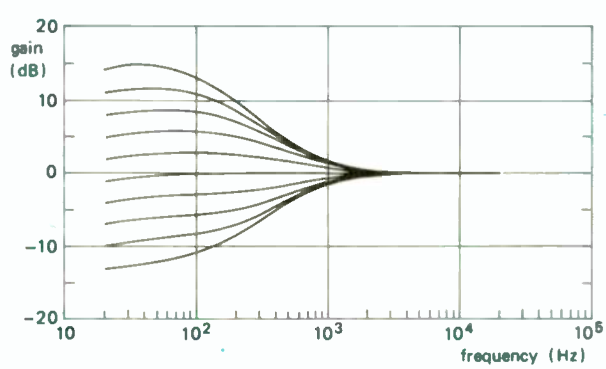


Fig.4. Example frequency response characteristic. Gain control range is +15dB to −12dB in 3dB steps.

SOURCE SELECTION

Series connection of these circuits to provide integrated radio signal control for a car radio preamplifier is shown in **Fig.7**. The volume/balance control consists entirely of linear op-amp stages; bass control is a low-frequency signal control stage and treble control is a high-frequency signal control stage. Also incorporated in the IC (TEA6300) are an input buffer/source selector and a fader/mute control. These consist basically of linear op-amp stages with unity or variable gain, with switching to provide source and output selection. These functions too can be switched under the control of the I²C-bus. A sister IC to the TEA6300, the TEA6310, lacks a source selector but has an extra fader control input which is used as a hardware override to disable the fader control for a two-speaker system.

I²C BUS

Philips's two-wire I²C-bus (inter-IC bus) conveys serial clock pulse trains from the serial data and serial clock outputs of an eight-bit microcontroller. Synchronization of the two pulse trains is determined by the microcontroller. More slave devices can be connected in parallel to the I²C-bus, for example a frequency synthesizer; each slave device must therefore be defined by a unique slave address. The serial data (SDA) input is basically a three-byte word, each byte consisting of eight address or data bits. The first byte

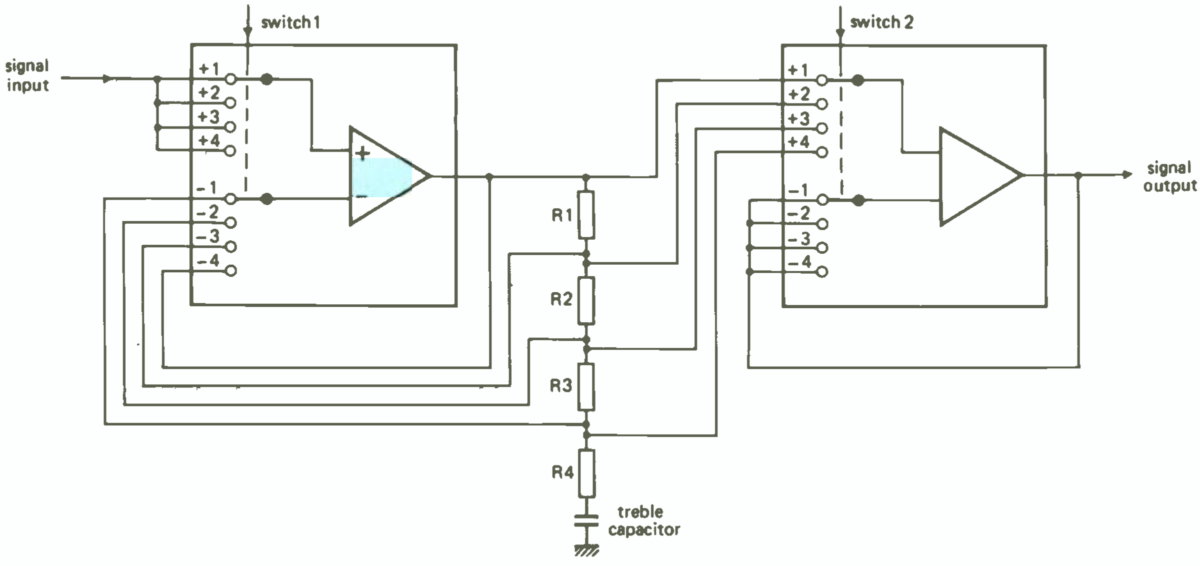


Fig.5. Adding a single capacitor allows the high-frequency response to be controlled. High-frequency amplification/attenuation is determined by the resistor values only, and the frequency range by the breakpoints established by the resistor and capacitor values.

contains the slave address, the second the slave parameter address and the third byte contains the parameter value data and system switching data.

The bus is bidirectional: the eighth bit of the slave address determines the direction of the parameter value data, which, for the TEA6300, is always from the microcontroller. Parameter values are latched in the I^2C-bus logic of the TEA6300 until changed by a further output from the microcontroller. The outputs of the latches drive fet switches which select the op-amp stage gain and therefore the analogue parameter value. The seven parameters in this case are

1. Volume control of channel 1, performed by switching the gain of cascaded linear op-amp stages.
2. Volume control of channel 2. Note that independent control of both channels permits balance control with a total range equal to twice that of the dynamic range of each separate channel.
3. Bass control of both channels, performed by switching the gain of the low-frequency signal control op-amp stages of each channel in parallel.
4. Treble control of both channels, performed by switching the gain of the high-frequency signal control op-amp stages of each channel in parallel.
5. Fader control of both channels, performed by switching the gain of cascaded linear op-amp stages.
6. Input selection (switch selection of inputs A, B or C).
7. Mute control, performed by switching 80dB attenuation into each output.

For the TEA6300 a logic high is between 3 and 12V and a logic low is between −0.3 and +1.5V. Pull-up resistors may be necessary on the I^2C-bus inputs, depending on the technology and supply voltages of master/slave devices connected to the I^2C-bus. A high-to-low transition of the SDA input while SCL is high defines the message start condition. Each message consists of slave address, slave parameter address and one or more consecutive bytes of data. A low-to-high transition of the SDA input while SCL is high defines a message stop condition. At the end of each byte the slave device holds the SDA line low during the acknowledged bit on the SCL line from the microcontroller to confirm the transfer.

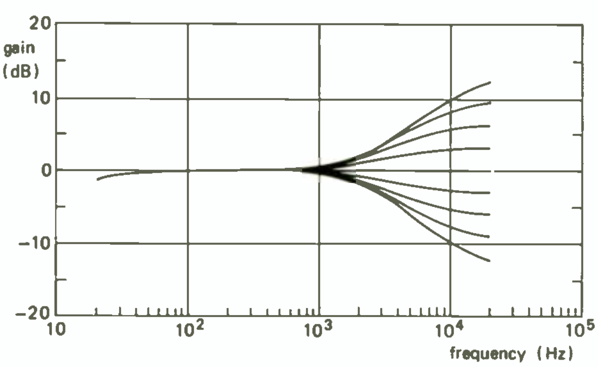


Fig.6. Example frequency response. Gain control range is +12dB to −12dB in 3dB steps.

TEA6300 typical performance data.

Supply voltage	7.0 to 13.2V
Gain control range	−66 to +20dB in 2dB steps
Low-frequency control range	−12 to +15dB in 3dB steps
High-frequency control range	−12 to +12dB in 3dB steps
Input sensitivity (for full output power)	50mV
Maximum input signal	1.65V
Operating frequency range	35Hz to 20kHz
Channel separation (250Hz to 10kHz)	92dB
Total harmonic distortion	0.05%
Signal-to-noise ratio	80dB
Operating ambient temperature range	−40 to +85°C

Since the system software defines slave address, slave parameter address and the parameter value data, the dynamic range and balance control are defined by the limits imposed by the car radio manufacturer's software. Therefore these parameters can be optimized to provide the required output voltage for the particular application. In addition, it is possible for the user to pre-set the value of a particular parameter for a selected frequency at the control panel. In this case, a pre-defined procedure stores the required parameter value, which is faithfully reproduced when the frequency is subsequently selected.

To realize this completely-integrated preamplifier on a single chip, with each parameter under software control and consisting of series-connected op-amp stages places stringent demands on stability, noise levels and distortion. The effective dynamic range is determined not only by the output signal level but also by the noise generated in the integrated preamplifier. Noise generated in the cascaded op-amp stages must also be reduced to a minimum. Typically, the signal-to-noise ratio is 80dB (measured to CCIR 468-2) with a supply voltage of 8.5V, dynamic range of −66 to +20dB and input/output signals of 50mV and 500mV respec-

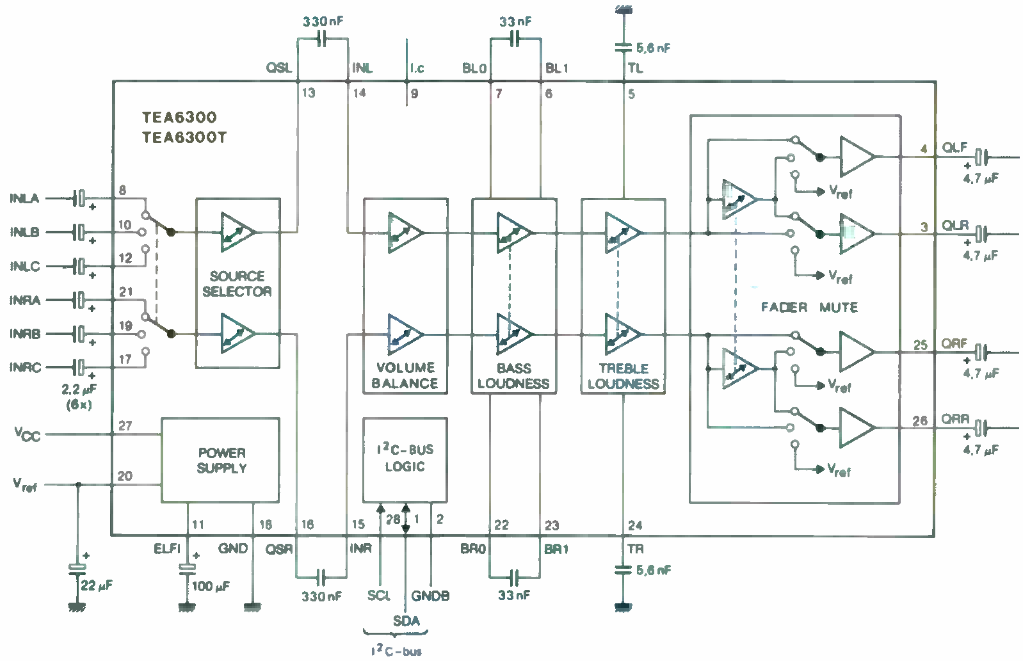


Fig.7. Car radio preamplifier based on the TEA6300. The volume/balance control consists entirely of linear op-amp stages.

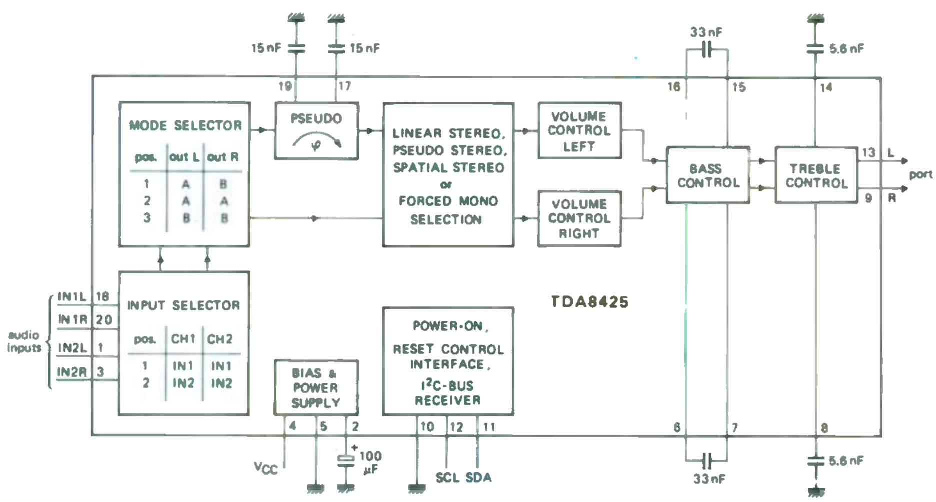


Fig.8. Hi-fi stereo sound processor for television receivers. Input selection, mode, volume, bass and treble are all controlled via the two-wire I²C-bus.

tively. Noise levels of this order satisfy the requirements for Dolby B and C noise reduction.

To reduce switching noise, offset voltage compensation is incorporated into the op-amp stages. The resistor values in the potential dividers are as small as possible to minimize offset current effects. These design precautions eliminate the audible clicks and plops normally associated with low-frequency signal switching. Total harmonic distortion measured under the above conditions is typically 0.05%; but signal clipping will occur at input signal levels greater than 1V with a gain of 20dB, and so the total harmonic distortion will then increase rapidly.

A second example of integrated audio signal control is the hi-fi television stereo audio processor of **Fig.8**. In this case, volume, bass and treble settings are normally determined by a remote control system. The data output from an infra-red remote control transcoder must either incorporate an I²C-bus interface (as in the Philips IC type SAA3028) or feed the remote control data as a serial data word into an input port of the microcontroller. In each case, the remote control data is processed in the micrcontroller and output on the SDA line to the TDA8425. Since both the TDA8425 and the SAA3028 are connected in parallel to the I²C-bus the necessity of a unique slave address for each device is immediately apparent (there is no chip-enable input with the I²C-bus system). The SAA3028 feeds data to the microcontroller on the I²C-bus whereas the TDA8425 receives data from the microcontroller as determined by the eighth bit of the slave address byte.

The TDA8425 has a volume control range from −64 to +6dB per channel in 2dB steps, with the same low- and high-frequency control values given in Table 1 for the TEA6300. Total harmonic distortion is typically 0.05%, for an input signal of 500mV with a gain of 0dB, over the frequency range 20Hz-12.5kHz. Signal-to-noise ratio (weighted to CCIR 468-3) at unity gain is 86dB and the stereo channel separation (30Hz-20kHz) is typically 85dB. Maximum data transfer rate using the I²C-bus is 100kbit/s. ■

Peter Krüger is with Philips Bauelemente at Hamburg.

Ban the bugs

It takes a special kind of person to stay up until 2.30a.m. in the morning of Budget Day to debate the availability of electronics surveillance devices to *Daily Telegraph* readers; but James Cran, Tory MP for Beverley in North Yorkshire, is just such a person. In a short debate, he discovered that not only the Government would not control the use of electronic bugs by a licensing system, it could not legislate to prevent their improper use because an acceptable definition of privacy was too elusive.

Cran's view was supported by a Labour MP, Barry Sheerman – probably not an avid *Daily Telegraph* reader – who said that the argument should not be about banning technology, but the "relationship of individual rights and the right to privacy in relation to changes in modern technology".

"The current law is a bugger's charter..."

The debate was very reminiscent of the joke definitions of the Three Laws of Thermodynamics which state: (1) One can't win, only break even, (2) one can only break even at absolute zero, and (3) one can't reach absolute zero. Thus MPs discovered: (1) once privacy has been breached there could be a legal remedy through a breach of confidence (2) one must know beforehand of the existence of a surveillance device and (3) one cannot discover these devices beforehand because they are designed to avoid detection.

Tim Renton, the Home Officer Minister, also stated that to extend the criminal law to cover surveillance or eavesdropping is not practicable. Either the law would be drafted too narrowly, in which case some new electronics gimmick would overtake the law, or too broadly, in which case the law would become unreasonable since it would encompass everyday electronics that use some of the qualities of a surveillance device. "Criminal offences", the Minister intoned, "must also be capable of clear definition"; something that eludes individual privacy.

In short, the secret is now out; the current law is a bugger's charter and nothing can be done about it.

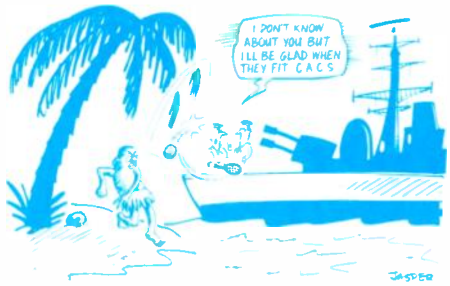
Notes on the House are by Chris Pounder.

"Something wrong with our bloody ships"

In a recent debate on the Royal Navy, it became clear that five of the Navy's modern Type 23 frigates will enter service without Command and Control Systems (CACS). This, according to the Government, "does little to impair intrinsic performance of [its] main defensive armaments but will impose a number of limitations on [its] use". It transpired that these 'limitations' will continue until 1992. Until then the new ships will be incapable of properly using their main missile defence, the Sea Wolf missile.

The Minister's problems in the debate began when he smoothly stated that "the original CACS 4 program was cancelled when it was realised that the computing power and capacity of the original design would be inadequate". This was as much as MPs were to get in way of explanation. Even when pressed, the Minister did not fully explain why the original specification for CACS was so far out; who was responsible and when problems were first discovered; whether Ferranti, the contractor, had failed to deliver what had been promised; whether Ministry of Defence officials had moved the design 'goal-posts' as the project developed, or even when the new CACS contract would be signed and how much it would cost.

This evasion resulted in a barrage of cynicism, led by Martin O'Neill, Labour's shadow defence spokesman. O'Neill concluded, "The pride of the British surface fleet will go to the defence of the country in a state in which they are less capable of defending themselves". Two other MPs were more rude; Menzies Campbell, the Democrats' defence expert, noted that the Minister was as convincing as a second-hand car salesman who told a potential customer that a used car on offer had "about two" previous owners; and Labour's Bruce George mentioned "rumours that the ships will be sent to the West Indies" or other sun-drenched



tropical "trouble-spots" in NATO's dangerous front-line.

Rumour has it that the Navy is placing recruiting adverts in this season's holiday brochures.

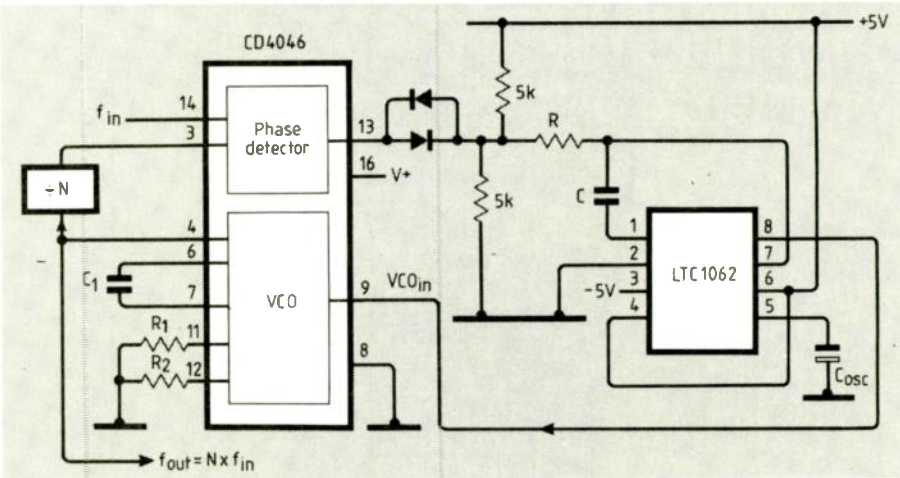
● The quotation at the head of this item is attributed to Vice-Admiral Beatty following the second catastrophic explosion which blew up a battle-cruiser during the Battle of Jutland, May 30, 1916.

Flying short of electronics engineers

Allan Rogers, one of Labour's front-bench experts on defence has uncovered that the RAF could be running dangerously short of qualified electronics engineers. In 1988, for example, the number of electronics engineers trained by the RAF was 808, but since 436 failed "to complete engagement" only 381 eventually entered the Service. When other job changes and retirements are taken into account, Rogers claims that the RAF lost 427 electronic engineers from its trained strength of 11 127; according to Rogers, too many "RAF personnel are voting with their feet" and leaving. His figures indicate a drop out rate of over 50% from the RAF training courses; and that the proportion of 'drop-outs' has progressively increased over the decade, and that all the engineering disciplines in the RAF are suffering similarly.

It is therefore perhaps fortunate that demand for electronics engineers is less than expected. Because of problems with late delivery and performance of the much-maligned Foxhunter radar, Rogers believes that 32 Tornadoes costing £500 million are mothballed in hangers at RAF St Athan in Wales at an annual cost of £60 000, whilst Tornadoes are still flying training missions with concrete ballast instead of the radars and so require less maintenance. If this were a Labour council, Rogers concluded, it would be surcharged, harassed by the press, removed from office and thrown into jail!

Low-pass filters for PLLs



Loop filters for phase-locked-loop applications can often be simple first or second-order types but when minimum output jitter and good transient response are required simultaneously, more attention has to be paid to the loop filter's design.

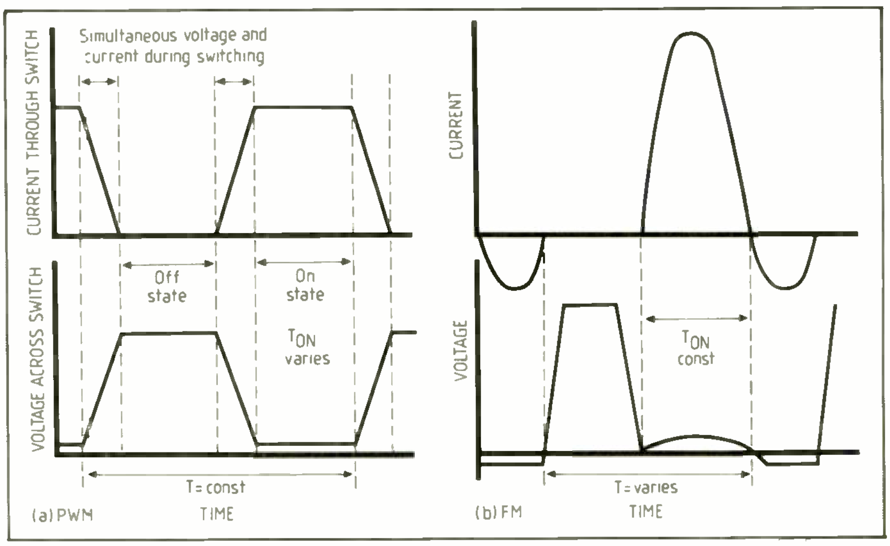
Fast transient response implies wide filter bandwidth and low VCO output jitter relates to ripple at the VCO input. To achieve low jitter and fast response, the low-pass filter needs high outband attenuation.

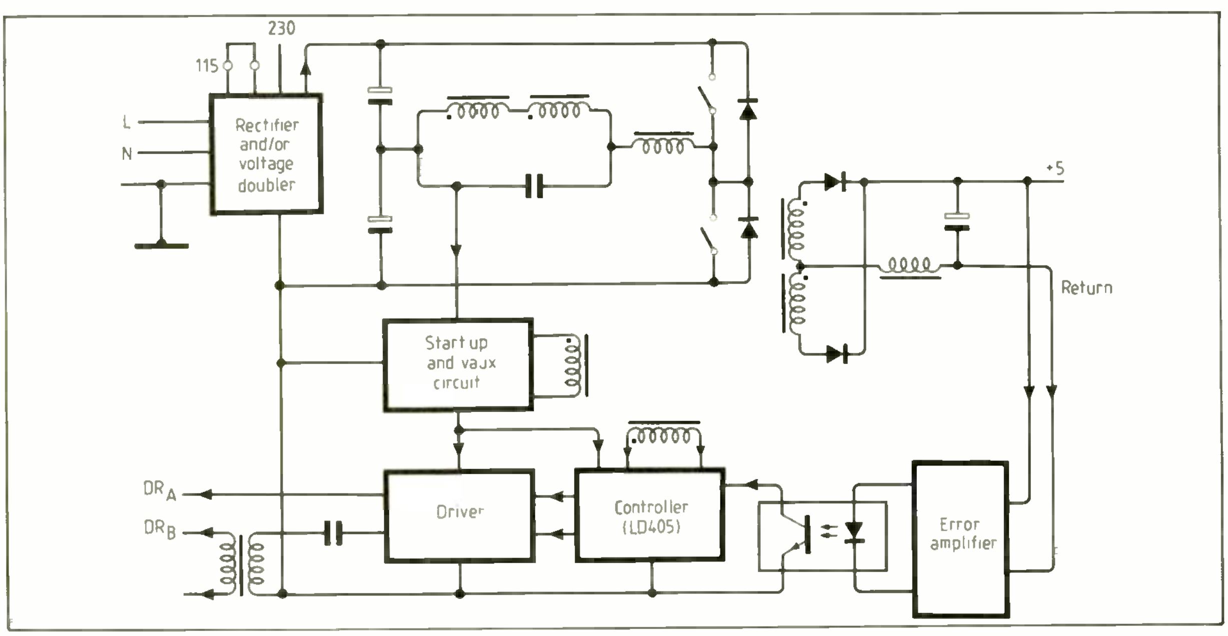
Such a filter based upon the LTC1062 low-pass filter IC is discussed in Linear Technology's Application Note 24. With the aid of empirical results, the note compares performance of an LTC1062-based filter with that of a passive RC filter, and it outlines clock sweepable bandpass/notch filters and programmable cut-off frequency filters. *Linear Technology, 111 Windmill Road, Sunbury, Middlesex TW16 7EF. 0932-765688.*

A 125W resonant-mode supply

In switching power supplies, efforts to decrease physical size by increasing switching speeds result in higher losses in the power switches, despite the use of mosfets. A detailed note called "Using the LD405 in a 125W resonant-mode power supply" explains how zero-current switching provides higher efficiency at higher frequencies.

A full resonant-conversion supply is presented in the note together with comprehensive design details. *Gennum Corporation, P.O.Box 489, Station A, Burlington, Ontario, Canada L7R 3Y3. 416 632 2996.*





APPLICATIONS SUMMARY

Audio level detection system

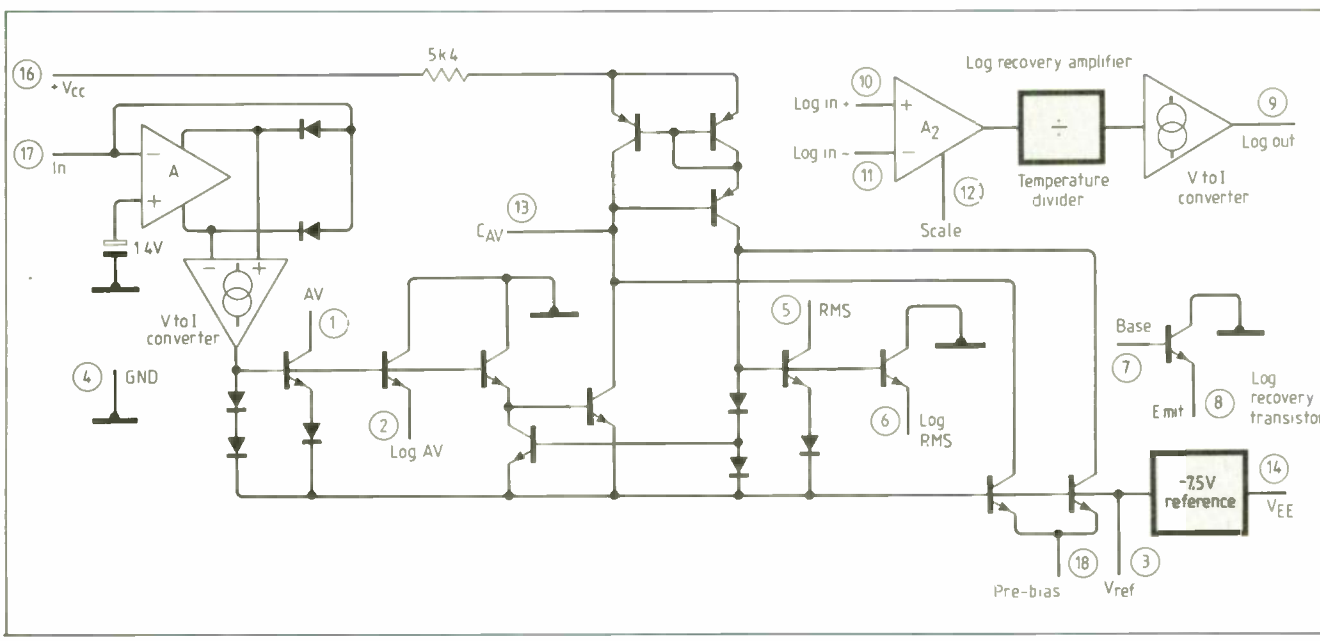
A precision level detection IC designed specifically for audio applications features both linear and logarithmic outputs, as this pin-connection option diagram shows. The device comes from a company little known outside the professional-audio area called SSM; in August 1988 PMI took over SSM and so it is likely that information about the company's products will be more widely disseminated from now on.

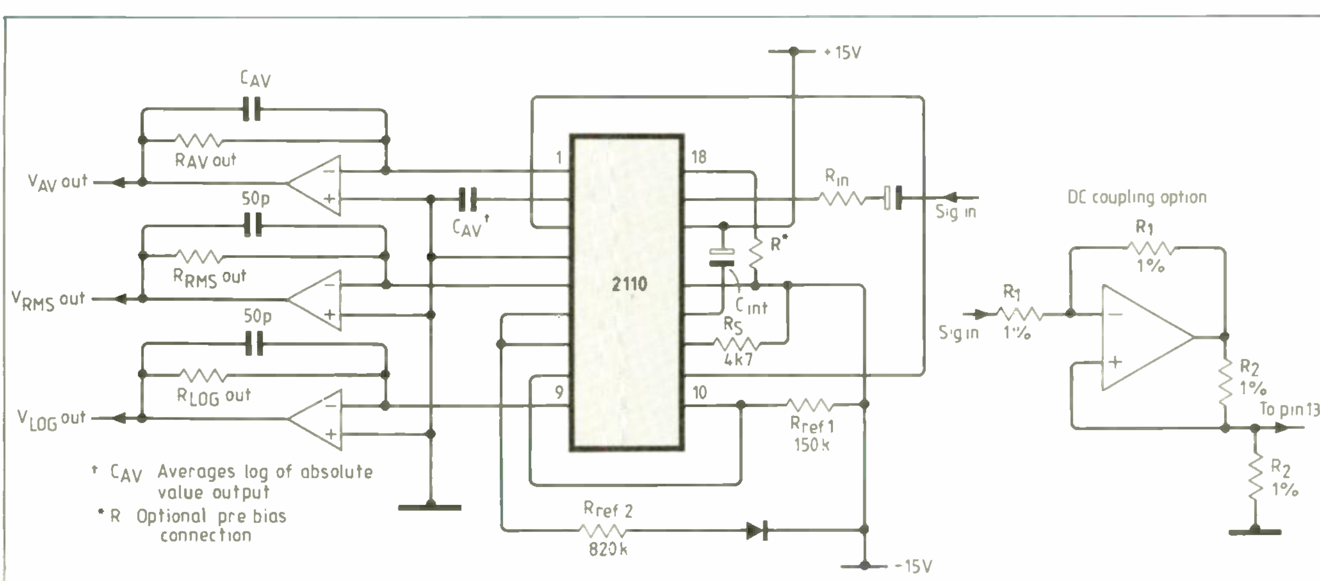
Unlike many ICs of this type, the SSM2110's logarithmic output can be internally compensated for scale-factor changes with temperature. It has true RMS and absolute-value outputs, the latter of which can be configured for peak readings and both of which also have temperature compensation on chip.

According to SSM's first data book since its incorporation, it is possible to achieve a 100dB dynamic range with the 2110, and its 'unique' pre-bias circuit allows dynamic range to be traded for faster response time at low signal levels.

Further applications information is included in the data book on this and other interesting professional audio devices such as voltage-controlled amplifiers, an 800pV/$\sqrt{Hz}$ noise microphone preamplifier, a four-pole VCF and 'music voicing system'.

PMI, Bourns Electronics, 90 Park Street, Camberley, Surrey GU15 3NY. Tel. 0276 692392.





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FRANK OGDEN
Editor

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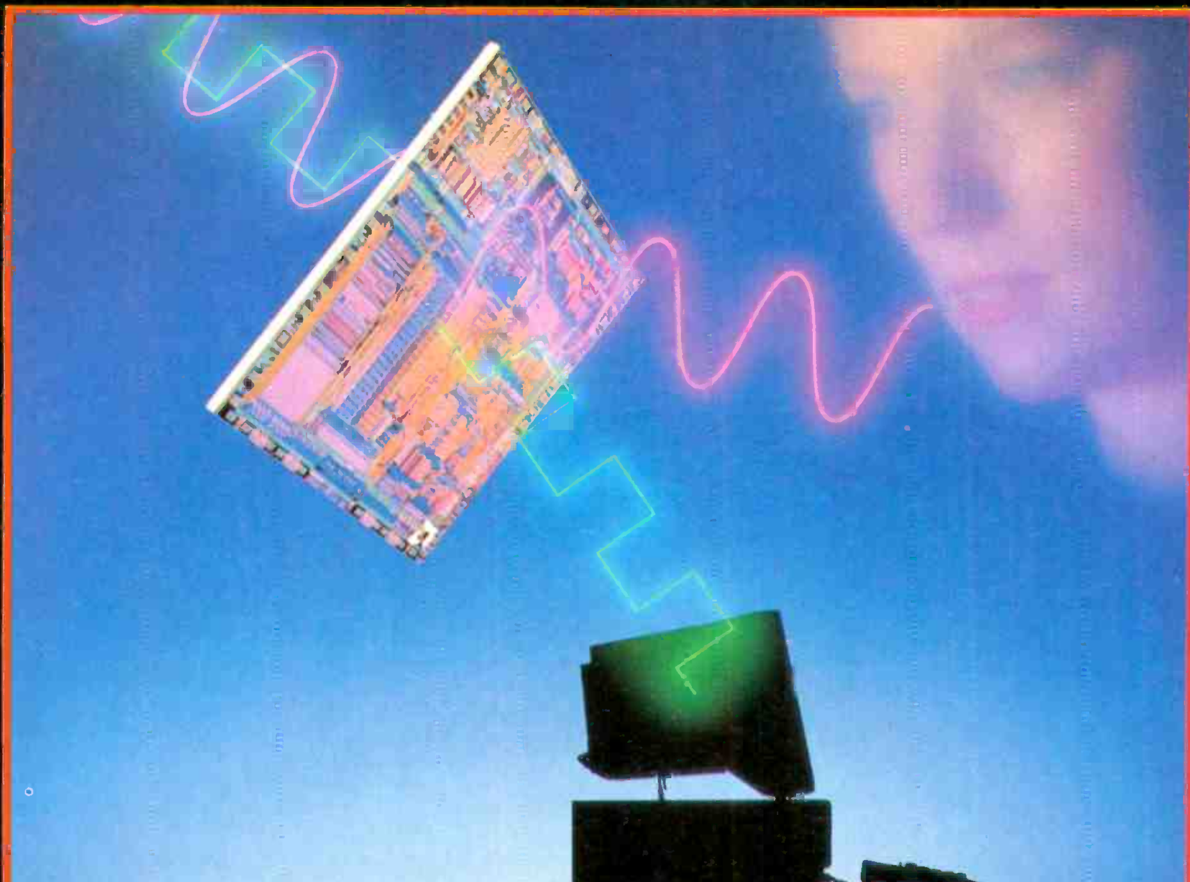
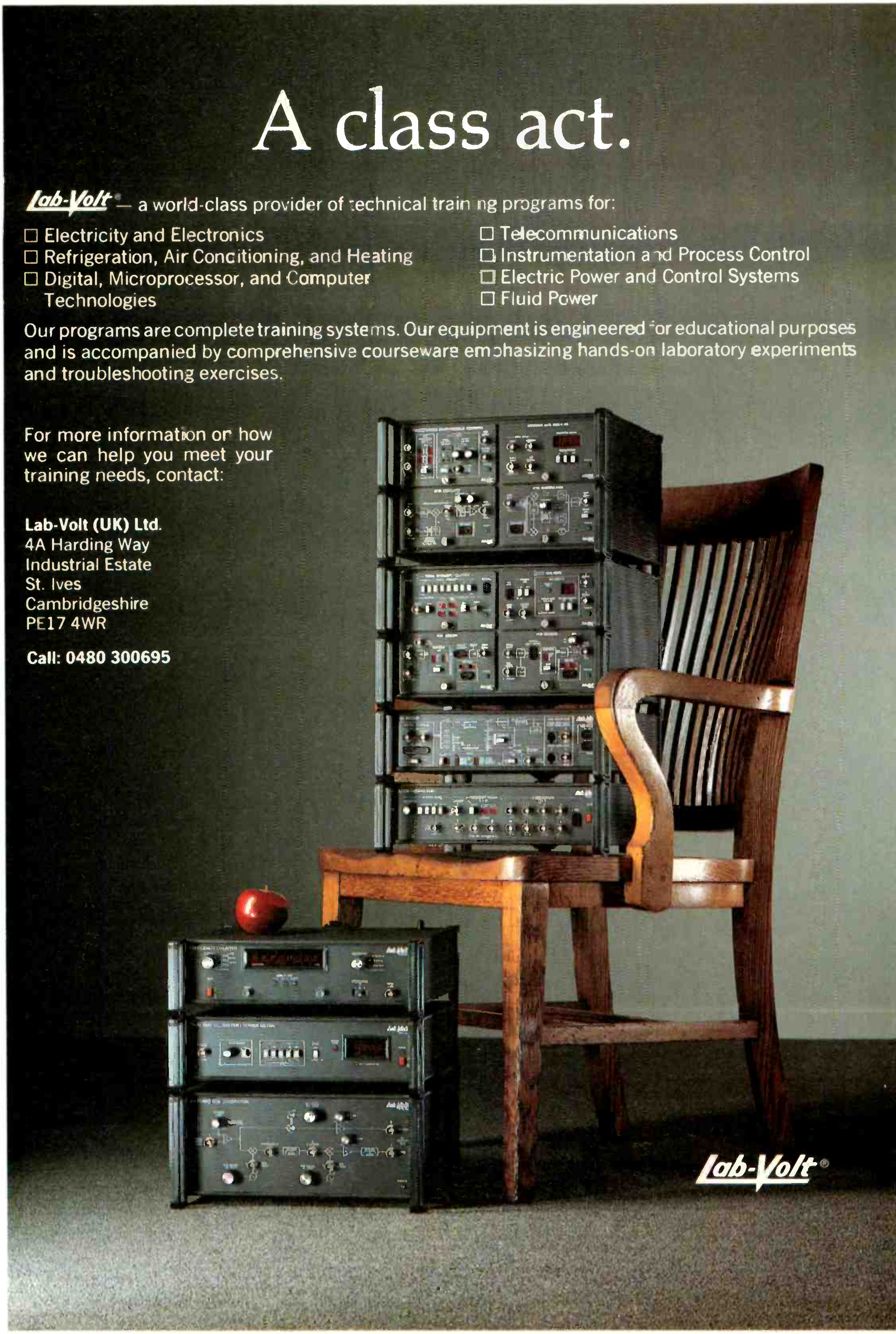
JUNE 1989

INDUSTRY INSIGHT



RS-232 protocol analyser uses an oscillosope as display medium to reduce cost, p. 595 ● Modem techniques extend the range of RS-232 links cost effectively, p. 597 ● Europe's new generation of telecoms equipment works at 2.4Gbit/s – but what next? p. 599 ● A novel technique makes optical-fibre transmission more attractive by reducing installation costs, p. 605 ● Optical-fibre transmission using coherent lasers with multiple wavelengths make possible low-cost upgrading of telecoms equipment for increased capacity, p. 606 ● Collision detection or token passing – which is better? Is there a simple answer? p. 608 ● Communications Editor Richard Lambley reports on mobile radio developments, p. 548.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RS232 protocol analyser uses oscilloscope display

To tell you which lines are high and which are low, you can use a cheap breakout box with leds, but to get the link right first time you need to know whether or not a parity bit is being used, whether the parity bit is odd or even, and how many stop bits are used. It is also helpful to know the data rate.

Hardware for a protocol analyser need not be too expensive; some switches and a handful of ICs will provide a good deal of digital information about an RS232 interface. But to make a practical protocol analyser that is user friendly, a display is needed.

A company familiar with designing low-cost test equipment, Thurlby, has noticed that many of the people responsible for sorting out problems with RS232 links already have an ideal display medium in the form of an oscilloscope.

> Since the RS232 standard defines very little, an RS232 interface can take a variety of forms. To some this indicates flexibility but to most it represents a nuisance – RTS/CTS or XON/XOFF, modem or terminal, CTS or DCD, the possibilities are manifold.

The Thurlby DA100 protocol analyser takes advantage of this observation. It connects to any DC-coupled oscilloscope with a bandwidth above 5MHz to display 32 characters of alphanumeric information indicating bit rate, data-word format and the data itself in ASCII or hexadecimal form. It is also possible to set up triggered data capture, so the oscilloscope also needs to have a triggerable time base.

If the RS232 transmitting device is suspect or there is no transmitting device available, the DA100 can also generate test data. For full monitoring and patching facilities there is a breakout box option, the DA102, that connects to the DA100 to allow full level checking and arbitrary patching of all 25 lines. There is also an optional liquid crystal display, the DA101, to replace the oscilloscope. Prices of the units excluding vat are £79 for the DA100, £49 for the DA101 display and £69 for the breakout box. ■

```
                         Menu tree         Action
SETUP
   FORMAT
          AUTO CHECK            ;Finds unknown baud rate, word format, etc.
          MANUAL                ;Baud rate data bits, parity, stop bits
                                (50-38400baud), 7 or 8, odd, even

   MODE ------------------------;ASCII, hexadecimal, count+ASCII

   TRIGGER
          EVENT                 ;Trigger byte true, data error, P line toggle
          TRG-BYT               ;Up to three hexadecimal bytes
          COUNT                 ;1-99 events
          DELAY                 ;0 to 9999 bytes

   OUTPUT
          TERMINATOR            ;CR & LF, LF & CR, CR, LF
          HANDSHAKE             ;True always, Xon/Xoff, Mark, space
          BIT 8                 ;0 or 1

VIEW
   DATA ------------------------;Views data continuously
   TRG DATA --------------------;Viws data and stops on trigger event
   BRK BOX LINES ---------------;Displays status or break-out box lines

SEND
   SINGLE ----------------------;Sends a simple ASCII string once
   REPEAT ----------------------;Sends ASCII string continuously

ANALYSE
   DATA ERRORS -----------------;Displays number of errors received
   BAUD ERRORS -----------------;Displays percentage error of bit rate
```

Menu options for the DA100 are displayed on the oscilloscope screen.

Thurlby's DA100 protocol analyser uses an oscilloscope at its display, showing bit rate, word format and the data.

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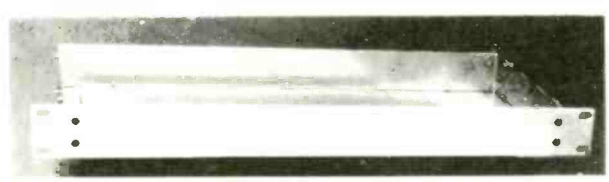

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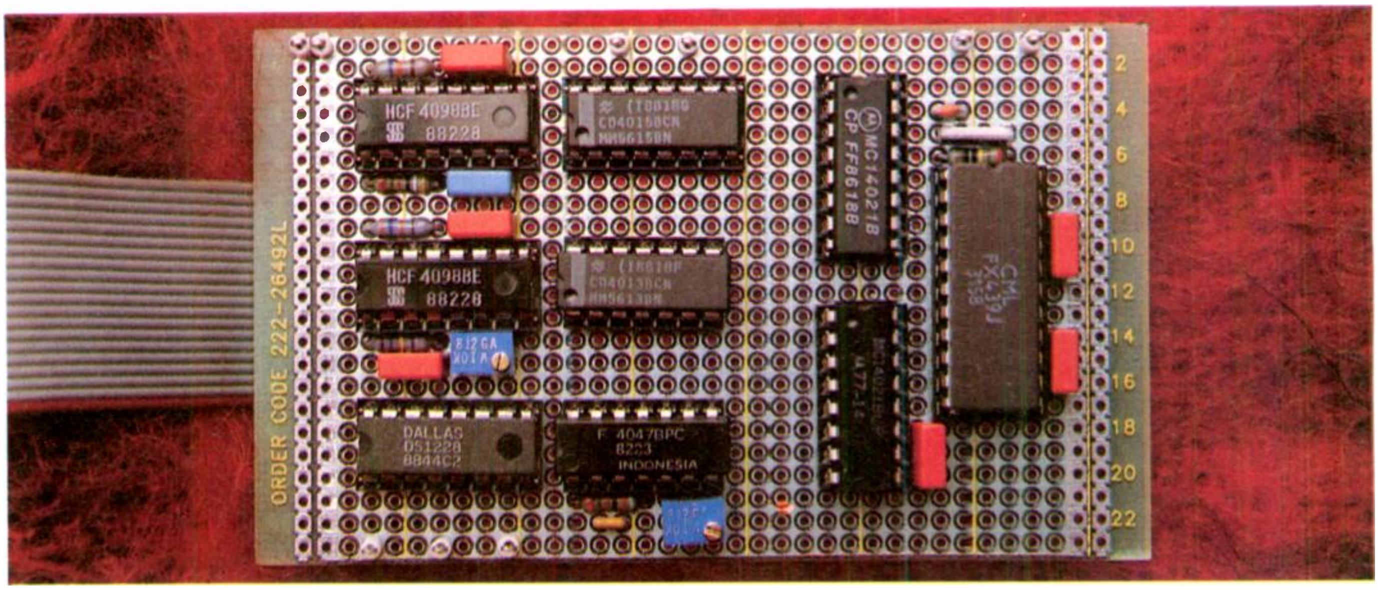
EXTENDING RS-232 LINKS



Andrew Dawes and Roger Lyons of Consumer Microcircuits describe a cost-effective method of boosting the range of serial data links.

Data communication between computer terminals over varying distances is achieved in many different ways, some very complex and expensive. The complex, expensive solution is sometimes prohibitive to smaller organizations. A basic, flexible serial data system to facilitate various types, sizes and speeds of installation has been formulated and adopted as an EIA standard – the RS-232C standard.

This interface is very flexible and can be used both for simple, simplex communication, with only two wires (signal + ground), or in highly complex full-duplex handshake installations using up to 25 different data and instruction interface lines. Basically the RS-232 format is serial, asynchronous data in the form of logic 1s and 0s whose amplitude levels are in the ranges −3.0V to −25.0V as a logic 1 (off) and +3.0V to +25V as a logic 0 (on). This data can be transmitted at rates of 50 to 9600 baud using current modem technology, and at up to 76 800 baud with high speed data transmission.

Since data transfer is asynchronous, to allow for variations between transfer and receiver timing clocks, there is a frequent requirement to stop the transfer to allow one or other terminal to catch up. This means that a stop signal and a corresponding start signal must be appended to the 'intelligence'. The number of data bits contained within each group varies.

One drawback of this type of data transfer is its range – the basic RS-232 interface is intended for distances of not more than 15 metres.

Data link

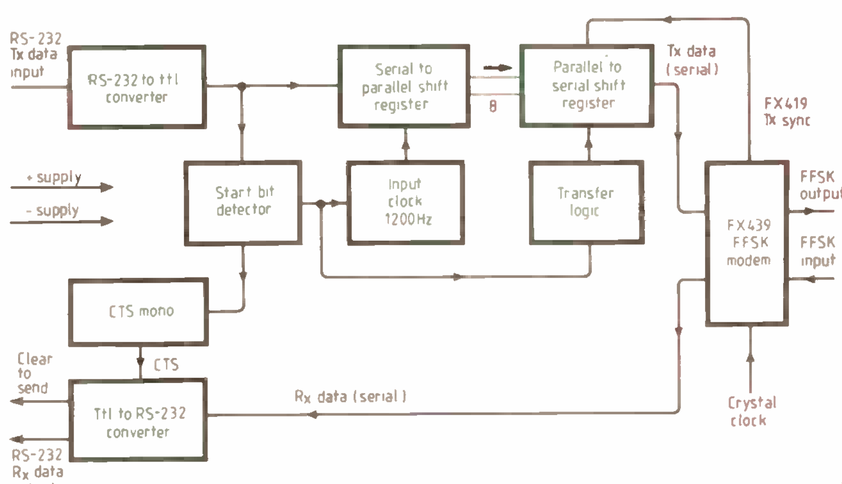
The 'Data Link' is a simple, low-cost, 1200 baud, full-duplex modem requiring only four lines of the EIA RS-232C system interface (TXD RXD CTS GND). This circuit increases the range of local data terminal communication to the limits of the chosen transmission medium. Due to its low-power requirement (a single 5V rail) and small size, this link could be an integral part of any desk-top or hand-held terminal.

In essence, the 'Data Link' consists of separate transmit and receive channels (**Fig.1**), each incorporating an FX439 FFSK modem. Input data (TXD) is converted from RS-232C to TTL and then to FFSK tones for transmission in the chosen medium, radio or telephone line. At the receiver the FFSK is demodulated and converted to RS-232C levels for the receiving terminal. Using an FFSK modem ensures good signal-to-noise ratio and bit error rate.

Transmit channel

Timing of the input and output data in the transmitter section is the key to the operation of the data link (**Fig.2**). Serial RS-232C

Fig. 1. Block diagram of the link, which provides bidirectional asynchronous communication at up to 1200bit/s.



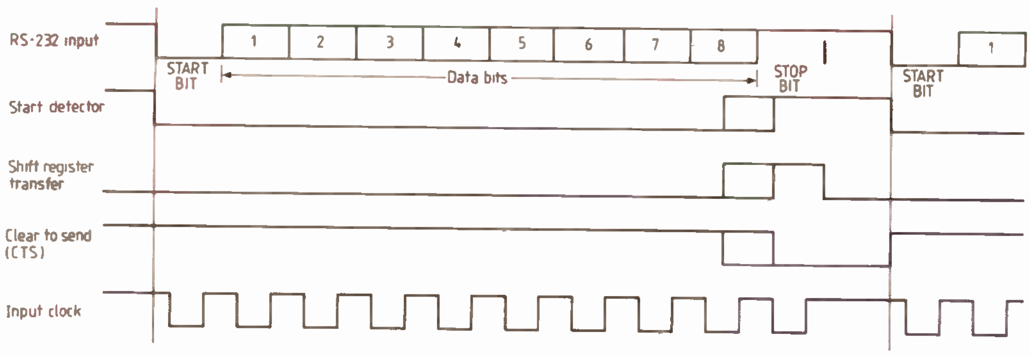


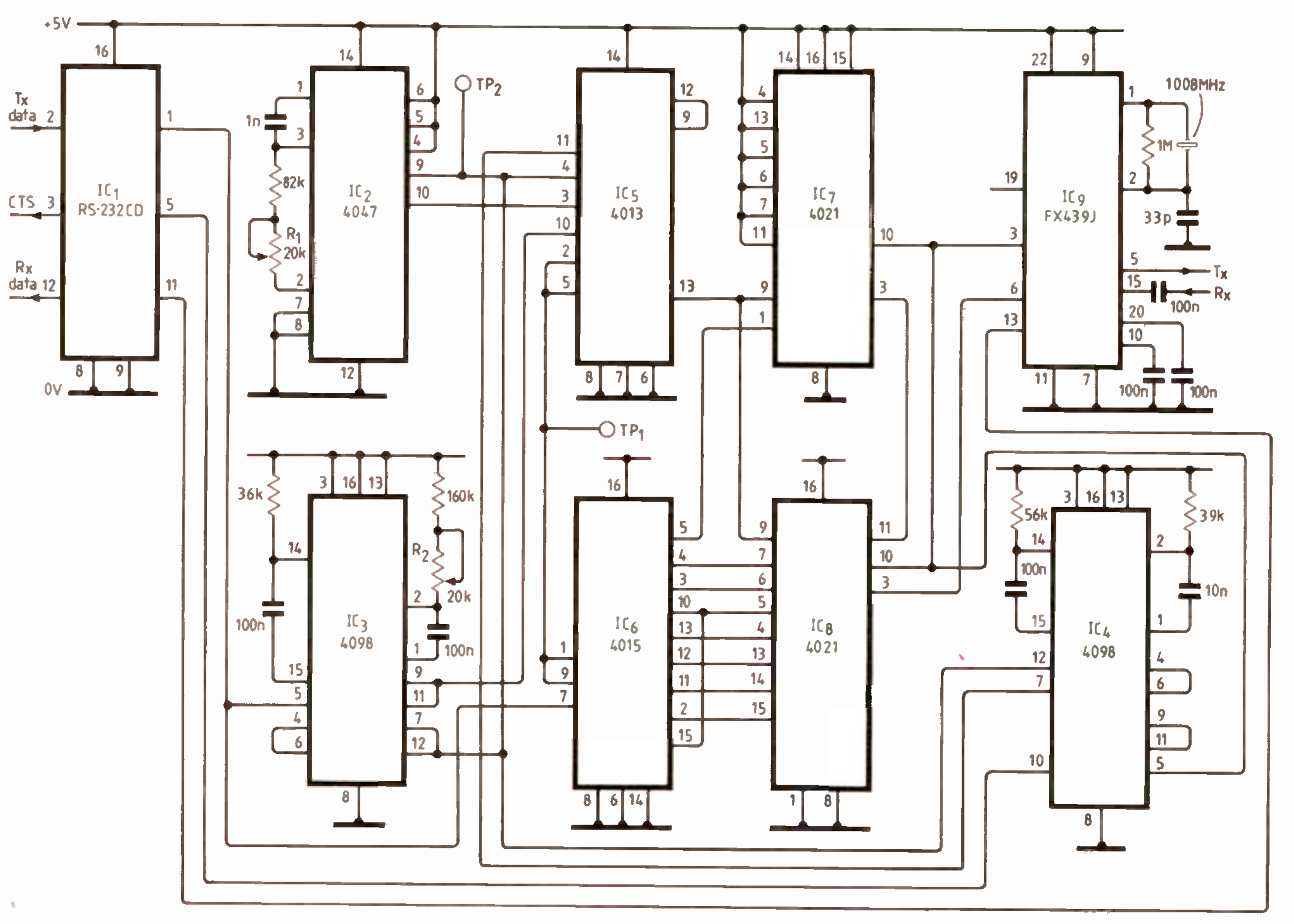
Fig.2. Timing diagram. Data is converted to parallel form within the circuit to allow for variations in timing between the input data and the FX439's clock.

data (TXD) from the transmitting data terminal (DTE) is converted to TTL at the circuit input by IC_1, the RS-232C to TTL/c-mos converter. Input data at the correct (TTL) level is applied to the serial to parallel shift register (IC_6) and the start bit detector (½ IC_3). Detection of the negative-going edge of the start bit enables the 1200Hz oscillator (IC_2 and ½ IC_5) for a period of nine clock pulses (this period is adjustable using R_2), which clocks the eight bits of input data into this register (IC_6). On completion of the input loading, after the ninth clock cycle, the eight bits are transferred to the parallel to serial shift registers (IC_7, IC_8) whilst the FX439 TX SYNC output (FX439 clock, pin 3) is low. This operation is carried out to allow for variations between the data input timing and the FX439 clock. The data, back in serial form, is then clocked out of the shift registers starting on the next positive edge of the FX439 TX SYNC, to be transmitted by the FX439 (IC_9) in a 1200 baud, (1200Hz/1800Hz) FFSK format.

The start bit (IC_8 pin 1) and stop bit (IC_7 pin 15) are 'hard wired' in the parallel to serial (output) registers, giving the final RS-232C format required by this application.

An advantage of the independent input/output timing is that, whilst one set of data is being clocked out of IC_7 and IC_8, more data can be clocked into IC_6 and the cycle can continue. To allow for phase variation between the RS-232C incoming clock and the FX439 clock, the clear-to-send (CTS) line is held low, disabling further transmission for

Fig.3. The complete modem. To set it up, TP_2 should be earthed and R_1 adjusted to give 1200Hz ±1Hz at TP_1; then, with RS-232C data applied in the recommended format (with 16 bit preamble), R_2 should be adjusted to produce a monostable pulse at TP_2 of 7.5ms.



a period equal to one clock cycle (≈833µs, set by R_1) from the end of the input stop bit.

FX439 FFSK modem

The FX439 is a single chip c-mos LSI circuit which operates as a 1200baud FFSK modem. Mark and space frequencies are 1200Hz and 1800Hz, phase-continuous with the frequency transitions occurring at the zero-crossing point. The transmitter and receiver sections work independently to provide full-duplex operation at 1200baud. Data rate, transmit mark and space frequencies and synchronization are all derived from a highly stable crystal oscillator. The on-chip oscillator of the FX439 is capable of working at one of two pin-selectable input frequencies, a 1.008MHz or 4.032MHz crystal or clock pulse input. The device includes circuitry for carrier detection (although for simplicity the function is not used in this data link) and a facility for recovering the received clock. Carrier and data channel filtering is performed by on-chip analogue switched capacitor filters, resulting in good overall dynamic performance.

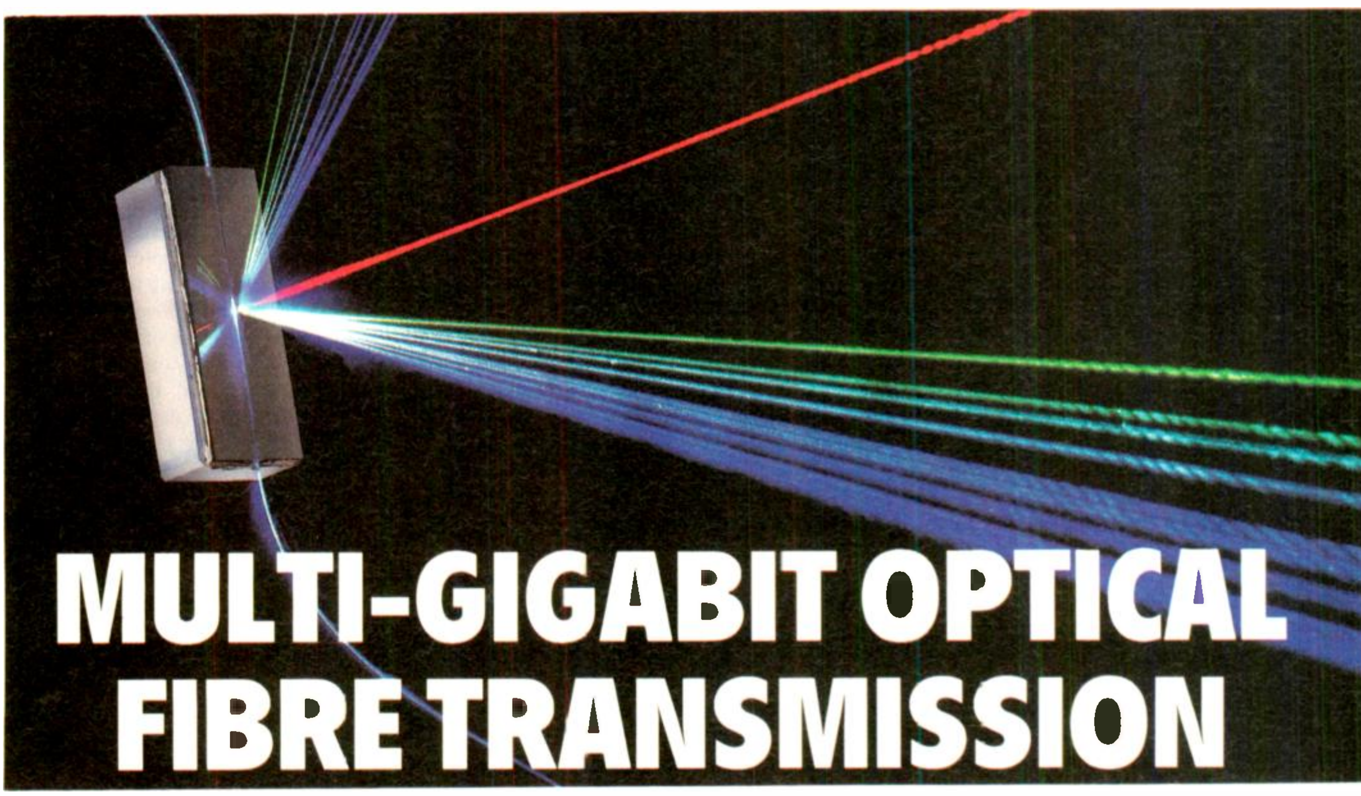
Few external components are required, with transmitter and receiver enable functions being pin-selectable and available for incorporation into the data link for further current saving when in standby mode.

The FX439's receiver converts the FFSK data to TTL. This data is in the correct format and only requires to be level converted back to RS-232C standards again using IC_1.

To enable the FX439 to synchronize properly, it is recommended that 16 bits (ideally as bit reversals) should be transmitted as preamble before the data proper is loaded; however, a shorter preamble may prove adequate. The communications program must monitor the CTS line and transmit only when this line is active (high). ■

● A data sheet and application note on the FX439 can be obtained from Consumer Microcircuits Limited, 1 Wheaton Road, Witham, Essex CM8 3TD, tel. 0376-513833.

Two prototype 'data link' modems were produced, using one-off component and device prices, for less than £50.



MULTI-GIGABIT OPTICAL FIBRE TRANSMISSION

A diffraction grating like this one can be used to extend the cavity of a semiconductor laser, resulting in thinner, spectrally pure beams.

If data rates in telecommunications are to rise above 10Gbit/s, more efficient ways of getting data down optical fibres will need to be looked at. Brian Debney of Plessey's Allen Clark Research Centre discusses one of the main alternatives.

Optical fibre has been in use in commercial systems for over ten years but the bandwidth provided by the fibre medium has to date been barely utilised. Single mode silica fibre with low attenuation windows centred on wavelengths of 1300 and 1550nm have available a total frequency bandwidth of some 20 000GHz corresponding to approximately 200nm. This could in principle be used to carry several thousand gigabits per second of data.

Present generation digital telecommunications systems employ the highest transmission data rates using fibre optics, the highest capacity installed links are at 565Mbit/s within the UK, and between 1 and 2Gbit/s in the US and Japan. These systems are clearly not limited by the bandwidth of the fibre, but by the optoelectronic components for transmitters and receivers and the electronic circuits associated with the time-division multiplexing (TDM).

Historically the trend in telecommunications systems development is ever upwards in capacity. The next generation of telecoms equipment in development within Europe is for 2.4Gbit/s and we can expect that the demand for even higher data rates will emerge. This view is reinforced by current research and development leading towards the future integrated broadband communications networks (IBCN) for providing broadband services via optical fibre for both business and private subscribers. A major European research programme called RACE (Research and development in Advanced Communication technologies for Europe) is underway with the goal of establishing a pan-European IBCN.

The need to carry interactive broadband services including video down to the subscriber will give rise to a massive increase in the demand for transmission capacity both within the subscriber loop and the trunk network. Current optical fibre research and development is therefore keenly addressing transmission technologies which could achieve these high capacities. Single channel TDM using direct detection, wavelength division multiplexing, and coherent optical transmission techniques are some of the key technologies and these will be described further here. For the purpose of discussion and comparison we will consider a single fibre capacity of 10Gbit/s.

Limitations of existing systems

Present day optical fibre systems are based on the principles of intensity modulation of an optical source and direct detection of the power modulation of the received signal (IM/DD), **Fig.1**. Combined with time division multiplexing this is the basis of modern telecommunication systems.

Extending the principles to 10Gbit/s and beyond presents major challenges to electronic and optoelectronic technologies because of the requirements on bandwidth for the transmitter, optical receiver, amplifiers, and multiplexing electronics. At these very high data rates the chromatic dispersion properties of the fibre combined with the spectral width of the laser source is a serious limitation on the transmission distance as indicated in **Fig.2**. This relates to the feature that different optical wavelengths propagate at different velocities because of the wavelength dependence of the refractive index.

As a consequence the temporal width of an optical pulse comprising a range of wavelengths will expand as it propagates, resulting in intersymbol interference. This severely restricts the use of multilongitudinal mode Fabry Perot lasers. The distributed feedback (DFB) semiconductor laser, commercially available at 1300 and 1550nm wavelength, exhibits a single longitudinal mode output whose narrow spectral width significantly reduces the effect of dispersion. However, even with this type of laser the spectral broadening under direct modulation yields a significant dispersion penalty at 10Gbit/s.

Direct modulation of the output power via

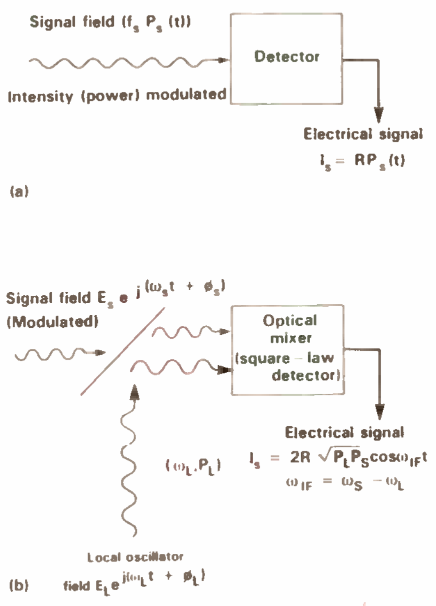


Fig.1. Principle of direct-detection optical communications (a) and principle of coherent optical detection (b).

the laser drive current at 10Gbit/s is technically very demanding and a possible solution which avoids the need for high speed modulation of the laser and the associated spectral broadening is to use a separate component for intensity modulation of the CW laser output. External intensity modulators based on waveguide structures formed in the material lithium niobate are now commercially available.

Experimental devices have demonstrated modulation bandwidths up to 26GHz, although no commercial devices suitable for 10Gbit/s are yet being produced. Semiconductor waveguide intensity modulators fabricated in GaAs and InP are also being researched with the potential for modulation at up to 60GHz.

Other difficulties associated with IM/DD systems operating at single channel data rates of 10Gbit/s or more are the relatively poor receiver sensitivities achievable. At these bandwidths the gain available from an avalanche photodiode (APD) does not yield any significant performance advantage over the simple unity gain PIN photodiode.

The design of wide bandwidth low-noise optical receivers to maximize transmission span is therefore a key issue. An example of a low noise design featuring a GaInAs PIN photodiode and GaAs fet front-end being developed at Plessey is shown in **Fig.3**. This has yielded a bandwidth of 6GHz with the expectation of achieving 10GHz and will suitable for a 10Gbit/s data rate.

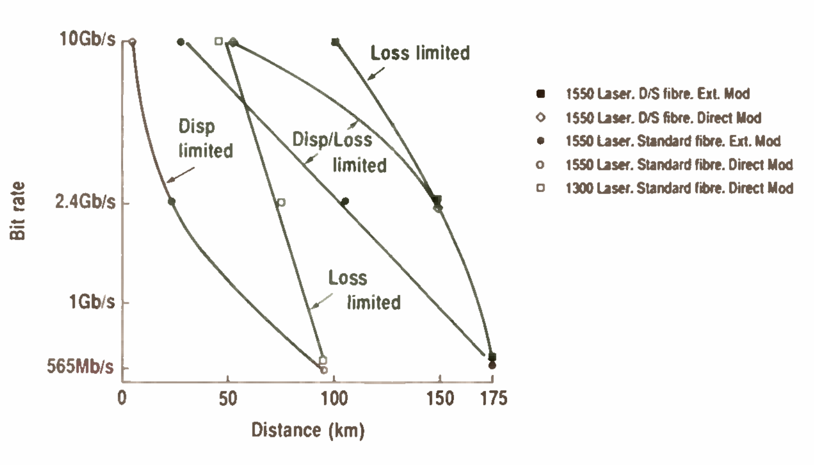
Currently, neither silicon nor gallium arsenide based IC technologies are available which could implement the appropriate 10Gbit/s functions. However, it is projected that within the next five years 10Gbit/s ICs could be achieved using gallium arsenide heterojunction bipolar technology with 1.5μm emitter feature size and ECL silicon bipolar technology with 0.5μm feature size. High data rate experiments carried out in recent years are summarized in Table 1.

Wavelength division multiplexing

An alternative to the single channel approach and the associated wide bandwidth devices is to adopt the principle of combining optical channels using the technique of wavelength division multiplexing (WDM). With this approach a number of low data rate channels, each operating on a different wavelength, are combined on to (multiplexed) and removed from (demultiplexed) a single fibre using wavelength selective components. The principle is shown in **Fig.4** for a point-to-point link.

The same total capacity can be achieved on the transmission fibre but using low bandwidth transmitters and receivers. A comparison between single channel TDM and multichannel WDM involves the trade-off in performance, complexity, and cost of the high and low-speed transmitters and receivers, multiplexing electronics, and

Fig.2. Maximum transmission distance versus bit rate showing limitations due to fibre attenuation and dispersion.



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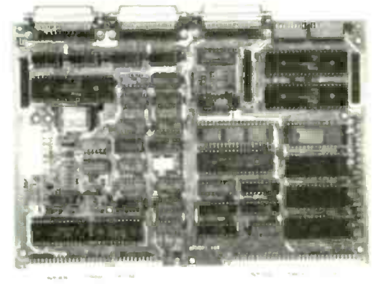

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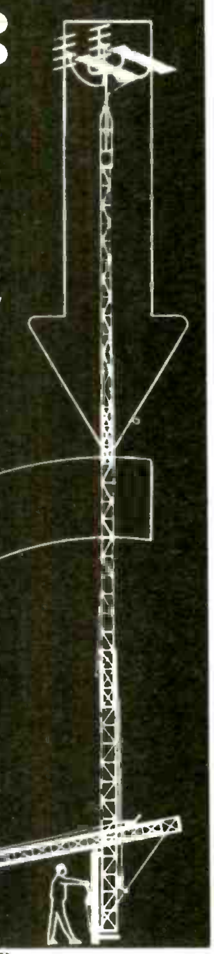

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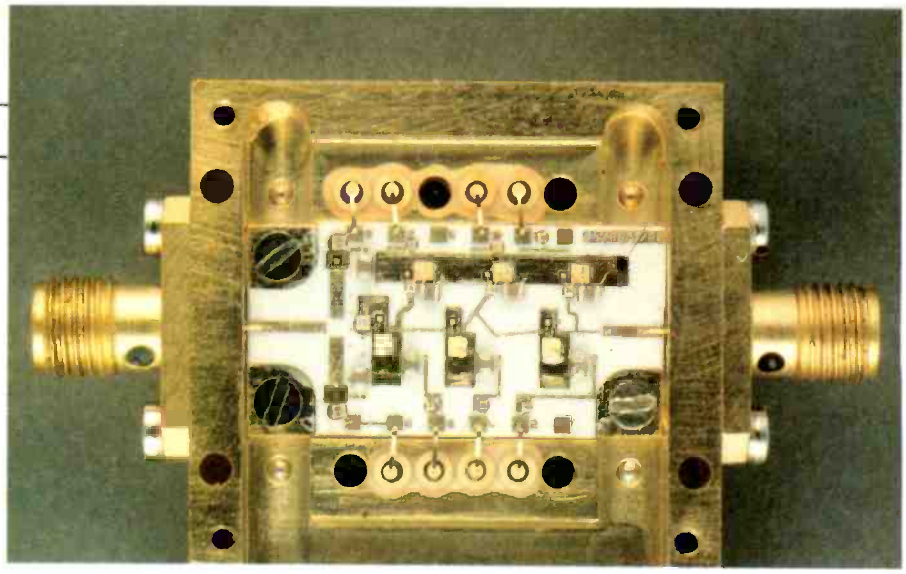


Fig.3. A low-noise GaInAs p-i-n/GaAs fet optical receiver front-end. This prototype module has a −3dB bandwidth of 6GHz.

WDM components. The technical challenge of WDM is to achieve a large number of discrete wavelength channels to make efficient use of the available fibre spectrum. This involves designing for close channel spacing; typically very much less than 10nm if an appreciable number (greater than 10) is to be located within a low attenuation window of the fibre.

A typical configuration for multiplexing 10Gbit/s could be 16 channels operating at approximately 620Mbit/s. A WDM component capable of multiplexing and demultiplexing 16 channels is shown in **Fig.5** and **6.** This component, designed to be operated with single frequency DFB lasers emitting in the 1550nm wavelength window, provides 7.2nm channel spacing and 2.4nm channel

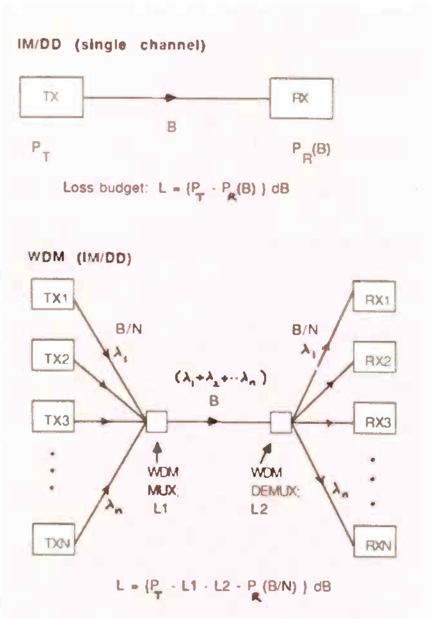


Fig.4. Use of wavelength division multiplexing to provide high transmission capacity.

bandwidth. The component shown has demonstrated a single channel insertion loss of typically 7dB, but 4dB should be attainable.

Coherent optical communication

The technique offering perhaps the greatest possibilities for efficient use of the fibre bandwidth is coherent optical communications. This transmission technique is in essence the optical equivalent of the superheterodyne radio principle in which a single-frequency laser replaces the RF or microwave oscillator as transmitter and local oscillator sources.

A fibre link employing coherent heterodyne detection is outlined in **Fig.7.** The powerful local oscillator laser is combined

Fig.5. Packaged 16-channel single-mode fibre WDM component. The device features a grating as wavelength dispersive element and a lithium-niobate concentrator.

with that of the weak incoming modulated optical carrier wave and mixed in a conventional semiconductor p-i-n photodiode. This results in amplification of the signal which appears on an intermediate-frequency electrical carrier as indicated in Fig.1.

An advantage of coherent detection over direct detection is the increase in receiver sensitivity, which is typically between 10 and 20dB depending on the modulation format. Unlike IM/DD where only intensity modulation or amplitude-shift keying is possible, coherent optical transmission offers the full gamut of modulation options involving amplitude, phase and frequency-shift keying. A further advantage of coherent detection, in common with the situation in radio, is the possibility of populating the fibre with many closely spaced optical carriers which can be accessed via a heterodyne receiver employing a tunable local-oscillator laser.

The principle is outlined in **Fig.8** which illustrates a configuration appropriate to a broadcast mode of operation which could be used to provide broadband channels in the subscriber network. The signals from a large number of transmitter lasers are combined using a wavelength independent star coupler so that all channels are present equally on every fibre.

An optical heterodyne receiver is strongly frequency selective, just as in radio, which means that the optical channels need only be of the order of gigahertz frequency spacing (typically around ten times the signal bandwidth) so that the fibre bandwidth is used very efficiently. In practice the transmission capacity which is accessible via this technique is limited by the tuning range of the

TABLE 1. Recently reported high data capacity experimental systems.

Date rate (Gbit/s)	Distance (km)	Wavelength (nm)	Modulation	Fibre type	Receiver	Source
8	68.3	1530	external	standard single-mode	APD/FET	Bell 1986
5	111	1536	direct	dispersion shifted	APD/HEMT	SEL 1987
10	80	1530	direct	dispersion shifted	APD	NEC 1988
11	81	1530	direct	dispersion shifted	P-i-n/HEMT	Bellcore 1989

Data rate (Gbit/s)	Distance (km)	Wavelength (nm)	Format	Source
2	170	1530	DPSK	AT&T 1987
4	202	1550	CPFSK	NTT 1987
4	155	1550	CPFSK	NTT 1988

Data rate (Mbit/s)	Format	Wavelength (nm)	Channels	Spacing (GHz)	Source
70	PSK/FM	830	10	6	HHI 1987
155	FSK	1540	16	10	Bellcore/ Hitachi 1989
200	FSK	1530	6	2.2	AT&T 1989
400	FSK	1540	10	8	NEC 1989
2000	WDM	1526-1560	10	170	Bellcore 85
1500	WDM	1527-1561	18	250	Bellcore 87

local oscillator laser, which for the tunable semiconductor laser devices currently under development is typically a few nanometers. This tuning range could provide 250 completely indepenedent channels at 140Mbit/s data rate, representing a capacity of 35Gbit/s.

As the single channel data rate gets higher it becomes increasingly difficult to realize the sensivity advantage of coherent detection. This is because the noise associated with the wide bandwidth receivers demands higher levels of local-oscillator power than are achievable with present semiconductor lasers in order to achieve local-oscillator shot-noise-limited performance.

Table 1 summarizes the highest data rate single channel experiments yet performed. In the last few years more attention has focused on the multichannel application of coherent transmission specifically relating to the broadcast concept described in Fig.8. Results of some experimental systems reported so far are also indicated in Table 1.

Within the concept shown in Fig.8 each output fibre from the star combiner carries a very high data capacity and so the concept can be modified to provide very high capacity point-to-point links. In this case the transmission fibre is terminated in a passive splitter with each output feeding a heterodyne receiver. Each receiver is locked to a particular data channel so that the total capacity of the fibre is simultaneously accessed in a manner similar to that depicted in Fig.4.

A coherent multichannel link using passive combining and splitting possesses intrinsic losses which are approximately 20logN dB where N is the number of channels. Techniques for lossless frequency addition are currently being explored which will substantially eliminate this. The transmitters and receivers though operating at a relatively low data rate are more complex than their IM/DD counter parts, but the resulting system offers great flexibility for adding capacity to a link and with the potential for accessing the largest transmission capacity.

And the future?

The techniques and technologies described are all at present within the realms of research and development although the level of background and development is different for each case and this must be taken into account in making comparisons. The field of coherent optical communications is relatively new, being a major field only within the last five years, but the component technology and systems engineering is

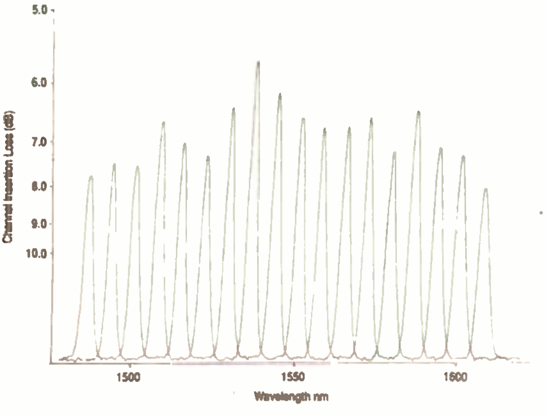
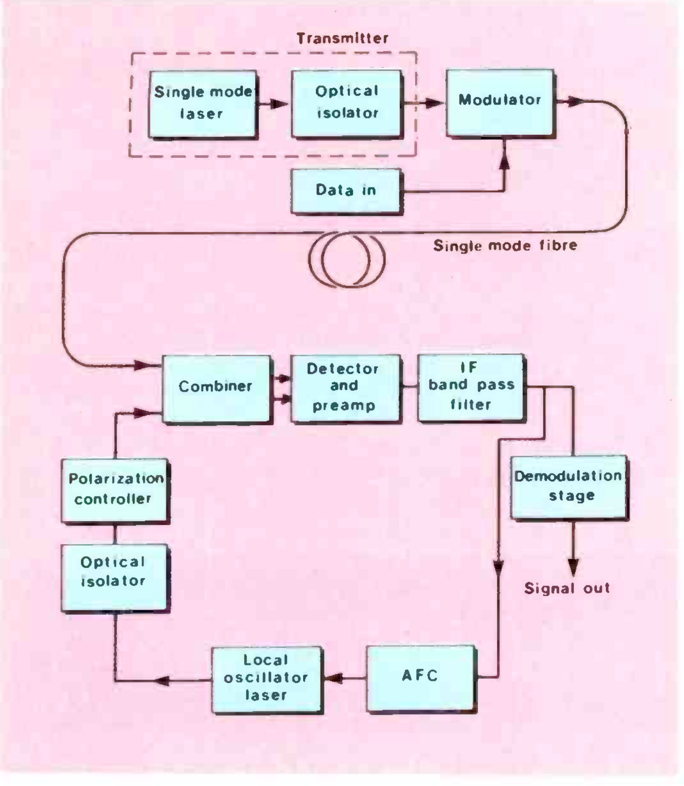
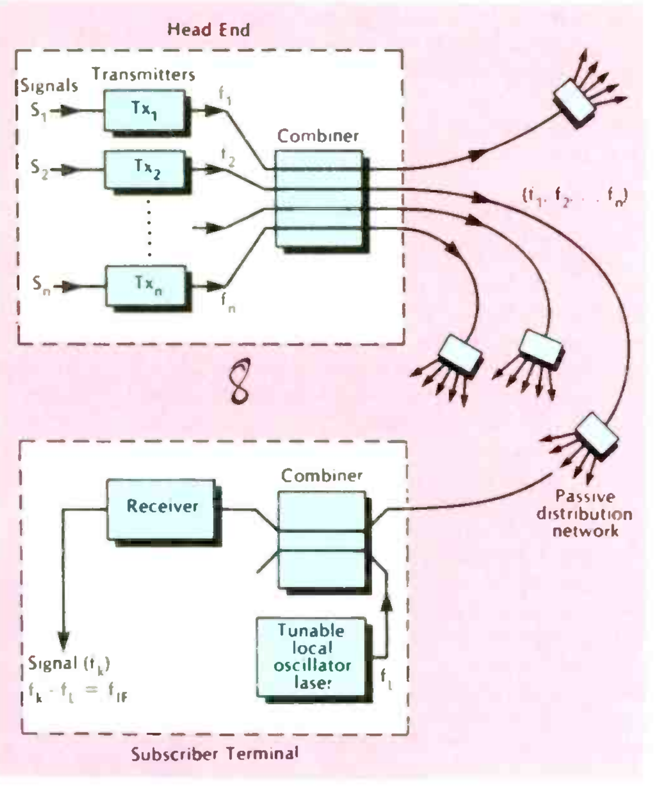


Fig.6. Passband characteristics for 18 channels of the component shown in Fig.5.

TABLE 2. Summary of the systems technology trade-offs for achieving a total transmission capacity B.

System technology	Features
Single-channel intensity modulation direct detection	• one transmitter/receiver • low receiver sensitivity; data rate B • wide bandwidth transmitter/receiver/electronics • capacity fixed by TDM
WDM N channels	• N transmitters/receivers • higher receiver sensitivity; data rate B/N • low speed transmitter/receiver • WDM insertion loss, cross-talk • increased system flexibility
Coherent detection N channels	• N transmitter/receivers • complexity of transmitter/receiver • higher receiver sensitivity; data rate B/N, coherent detection • low speed transmitter/receiver • combining/splitting loss; 20logN dB • flexibility to add capacity





maturing rapidly. This technology is beginning to move into the phase of addressing performance and stability outside the laboratory environment. An example of this is shown in **Fig.9** which shows a 140Mbit/s frequency-shift-keying system mounted in 19in racks for transportability.

The techniques described here all have relative advantages and disadvantages for providing very high capacity links and the main issues as currently perceived are summarized in Table 2. Loss budgets available for the fibre link using these techniques are assessed and compared in Table 3 for a link capacity of 10Gbit/s. These results suggest that both WDM and CMC techniques have possible link budget advantages over the single channel approach. The increase in receiver sensitivity obtained from operating at the lower data rate more than compensates for the losses associated with fibre combiners and splitters or WDM components.

For telecommunications the demand for capacity has so far been met by extension of the conventional technology of IM/DD and TDM. Wavelength division multiplexing, though researched and developed for many years, has so far not proved either technically or economically attractive enough to be implemented.

However, looking to the future and specifically at data rates in excess of 10Gbit/s, the technological demands of the conventional approach will become such that alternatives must be sought. Multiplexing in the optical wavelength or frequency domain has been shown to provide attractive candidate techniques. ■

Fig.7 (left). Illustration of the functional requirements of a coherent fibre-optic link using the heterodyning principle.

Fig.8 (above, right). A wideband distribution system using coherent transmission technology. This example illustrates the use of optical frequency division multiplexing (OFDM). The subscriber terminal 'tunes in' to the service on the channel with frequency f_k by adjusting the local-oscillator frequency f_l until IF ($f_k - f_l$) falls within the passband of the receiver.

TABLE 3. Comparison of link budgets for 10Gbit/s system capacity.

	Single-channel 10Gbit/s; IM/DD	WDM 16×620 Mbit/s	CMC 16×620 Mbit/s
Laser launch power: dBm	0	0	0
Combining loss (mux): dB	–	4	12.5
Splitting loss demux): dB	–	4	12.5
Additional losses (connectors etc.): dB	–	1	1
Receiver sensitivity: dBm	–22	–37	–51*
Link budget: dB	22	28	25

* CPFSK modulation

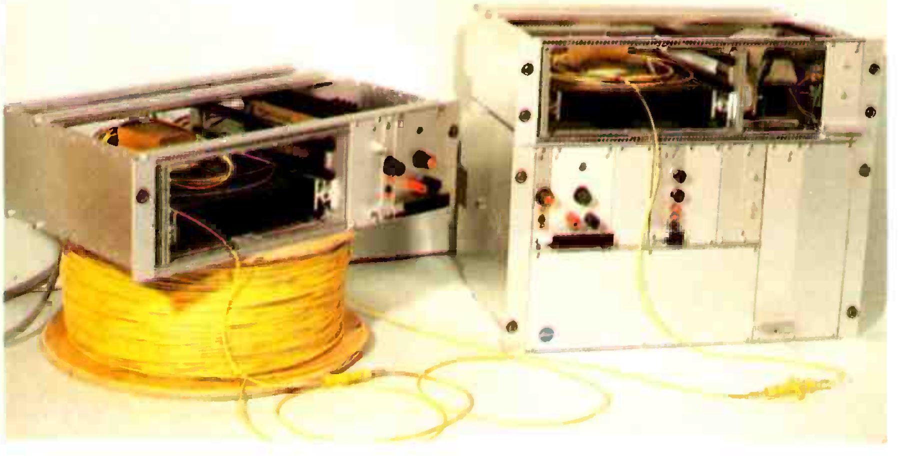


Fig.9. Prototype 140Mbit/s FSK coherent system constructed at Plessey and mounted in 19in racks. The transmitter is on the left and the receiver on the right.

BLOWN FIBRE – A NOVEL IDEA THAT MADE GOOD

A novel means of installing optical fibre inside buildings and outdoors has earned its inventor a medal for innovation as well as recognition from glass manufacturing concerns.

Known as blown fibre, the technique involves laying miniature conduits or ducts of polyethylene and running the optical fibre cables into them by blowing with compressed air. Because the technique is so straightforward and fast it is set to revolutionize the installation of optical fibre cables: by cutting the cost and time overheads of cabling it is likely to make optical fibres economic in fields up to now not considered appropriate.

Mick Reeve, the British Telecom research engineer who invented the unique system for installing optical fibre, was awarded the company's Martlesham Medal earlier this year in recognition of his idea. Reeve, who had spent more than 15 years researching the behaviour and performance of optical fibres, has shown that taking a radically new view of an old technology (cable making) can yield substantial benefits to the network operator. Not only did he invent the blown fibre process, but he also led the team in developing it to the point where it is now in large scale production and available from a number of commercial outlets. It is not often that European technology is licensed to Japan, but blown fibre is an example.

Like most of the best innovations, blown fibre is very simple. In the system, bundles of up to eight optical fibres, held together in a polyethylene sleeve, are simply blown into place down a small (3 to 6mm bore) tube or microduct. The microduct is tough and flexible and joints are made using ordinary push-fit connectors; it can be installed quickly and cheaply by unskilled labour. Once the microduct is safely in position, the fibre bundles can be blown through, using compressed air. The fibre moves briskly – at about walking pace – taking bends, junctions and vertical rises and falls in its stride, so the system works just as well inside buildings as outside under the pavement. Using tandem blowing heads the fibre can be blown in continuous lengths of several kilometres, without splicing.

When more capacity is needed on a route, the old bundles can be blown out and replaced with larger ones very quickly and cheaply. The whole process is fast, efficient and virtually foolproof – and both installation and upgrading costs are reduced.

How it works

The pace of optical fibre cable development at BT's Martlesham research laboratories was increasing after 1980, when Mick Reeve was put in charge of the Optical Cable Research Group there, working closely with all the major UK cable manufacturers to develop and apply new strain measurement techniques for optical fibres.

Mick Reeve, inventor of the blown fibre technique (picture from BT).

By 1982, it was very clear that optical fibres represented the way ahead. But there were still urgent practical problems to be solved. In particular, no-one had devised a wholly satisfactory way of putting the actual fibres in place, cheaply and efficiently, under field conditions, without straining or damaging them. It was at this point that Mick Reeve and his colleague Steven Cassidy began looking at possible installation methods. Compressed air had advantages as an installation medium but initial experiments using a bung attached to the end of a bundle of fibres were disappointing, and since the fibres were effectively being pulled along, they were being put under strain.

The breakthrough came when the fibres were observed to continue snaking through the tube even when the bung had left the end of the tube. Close examination of the experimental rig showed that the bundle of fibres was being carried forward by the viscous drag set up by the turbulent airflow around it. Instead of being pulled just from the end, it was tugged at every point along its length by the moving cushion of air.

Then the development work began. The microducts has to be just right – with the right bore and the right slip agents in the polymers. The design of the fibre bundles and the sleeve that held them together was critical, both in terms of signal loss and flexibility. Colour-coded fibres were needed, so that field engineers could tell which fibres to splice together. And there were other practical improvements to be made, such as the inclusion of a thread in each fibre bundle to make it easier to strip off the coating. Above all, it had to be shown that the production of the fibre cable could be scaled up to allow large quantities to be produced without quality problems.

The first installations

Mick Reeve's group set up an experimental cable-making plant on an industrial estate next door to the Martlesham site, giving them the opportunity to make cables using full-scale commercial extruders. As the practical problems were overcome one by one, the momentum increased and by late 1984 the blown fibre system was ready for a first trial installation, in Leeds. The result confirmed it – blown fibre worked just as well in the real world as it did in the laboratory.

After further successful field trials, blown fibre was used outside British Telecom for the first time in 1986, in a system carrying cables under the runways to the new Terminal Four at Heathrow Airport. The same year saw the first licensing agreement signed with Optical Fibres Deeside and the beginning of blown fibre installation in the British Telecom City Fibre Network in London.

Since then the pace has been stepped up even further, with the introduction of support tools such as tandem blowing heads and the ingenious rosette pans that allow installation teams to blow fibre in two directions at once. RAF bases such as Lyneham, Oldham and High Wycombe have been given multiple fibre optical cable routes. Blown fibre has now been used inside a customer's building for the first time, at British Petroleum's new headquarters at Hemel Hempstead.

The system has now been licensed to the largest fibre makers in the United States and Japan, Corning Glass and Sumitomo. ■

COHERENT TECHNIQUES FOR HIGHER FIBRE

Scarcely a month seems to pass without one or other telephone administration claiming a first or record in the field of optical fibre transmission, leading one to wonder whether the whole affair is not just an exercise in technical one-upmanship. It is, however, possible to distinguish some genuine breakthroughs. One such is coherent transmission.

Notwithstanding the undoubted advantages of single-mode over multi-mode transmission, existing optical systems are still remarkably primitive. In terms of exploitation of the optical ether, they are still at a stage of development equivalent to that of the spark era of radio. Despite the dramatic increase of digital bit-rates transported down the optical fibre medium, the method of transmission is remarkably impure, occupying large frequency bandwidths. This has been imposed by the technology available, but new techniques have emerged allowing multiple-frequency operation in the same fibre. Continuing the same analogy, the transmitters are now adjusted to operate on a single frequency, with heterodyne detection techniques employed for reception.

The advantages of such a system are truly dramatic in terms of the cost reductions they make possible. Coherent transmission, a technique which can increase the signal-handling capacity of existing optical fibres at least ten-fold, was first exploited operationally last autumn by British Telecom. The upshot was that the hair-thin strands of glass currently carrying up to 7500 calls at the same time could now be capable of carrying 75 000 or more conversations.

At the European Conference on Optical Communications, taking place in Brighton, the company announced that it was the first in the world to demonstrate coherent optical transmission over the operational network, outside the laboratory.

Dr Tom Rowbotham, of British Telecom Research Laboratories, explained that whereas previous demonstrations of coherent transmission had been made on the laboratory bench or under other controlled conditions, these trials were the first to be made over an existing optical fibre cable, in this case more than 170km long and without any intermediate signal amplification.

The success of this operation was said to offer the real opportunity to establish direct fibre links, of virtually limitless capacity, between cities as far apart as London and Birmingham. More dramatically it offered network operators the opportunity to increase the message capacity of their systems without installing further cable plant. The growth of telephone and data calls (currently 7 percent per annum in Britain) could be met by installing new, coherent transmission equipment re-using existing cables rather than having to provide additional complete systems alongside existing ones at much higher cost.

While existing optical fibre systems can carry up to 7680 conversations or data calls, which is no mean achievement compared to a few years ago, these systems still waste most of the capacity of the fibre medium by occupying the bandwidth of the fibre with only one transmission.

By comparison, the new fourth-generation optical systems, which researchers have demonstrated and must now refine, can split the frequency spectrum in a fibre and send different groups of messages on separate wavelengths. Each of these carries a different communication channel and they can all go down the same optical fibre "pipe". At the far end it can be arranged for the receiver to filter and sort them out, without interference or crosstalk.

BTRL's demonstration of coherent transmission last autumn employed lasers operating on the single wavelength of 1550nm, with a typical spectral linewidth of 50kHz. In these tests, digital test equipment was used to simulate calls and count bit-errors, rather than using live messages. The 176km route ran from Cambridge – Bedford – Cambridge – St Neots – Cambridge, making use of spare capacity of already installed conventional single-mode fibre temporarily available.

Multiplexing

Having demonstrated coherent transmission with a single wavelength, the next task was to interleave multiple wavelengths on the same fibre, a technique termed wavelength-division multiplexing. This was achieved in March of this year on an unregenerated fibre in the optical submarine cable between the Cumbrian coast and the Isle of Man. With this achievement British Telecom became the first carrier to use optical wavelength division multiplexing over its operational network.

In this exercise the BTRL research team combined the outputs of distributed feedback lasers operating on wavelengths of 1525, 1536, 1546 and 1557nm to feed one of the fibres in the cable. One laser was modulated at 140Mbit/s, the other three at 565Mbit/s, all four outputs being multiplexed on to a single fibre using a combination of passive and wavelength-sensitive fibre couplers. The operation of three channels at 565Mbit/s and one at 140Mbit/s increased the capacity of the system by 13 times, to 24 960 telephone channels. This was equivalent to operating the complete fibre system at 1.8Gbit/s.

The wavelength spacing of the four separate outputs was significantly closer – by an order of magnitude – than that achieved in earlier trials of wavelength division multiplexing. It was also the first time that WDM had been used in the field using fully-packaged and commercially available components.

While wavelength-division multiplexing and coherent transmission are the key to dramatically increasing the capacity of fibres, including those already installed in the ground, a number of options remain to be tested and proven, before customers have the full benefit of the techniques. Nonetheless, these two demonstrations prove that unregenerated systems can be readily upgraded in the future at minimum cost to provide direct increases in capacity. The same benefit applies with equal force to longer systems incorporating optical amplifiers, which are able to handle multiple transmissions without difficulty. ■

ETHERNET VERSUS TOKEN RING

Collision detection or token passing: which is better? Chris Bard of Synergy says there is no simple answer.

For simple situations, the design of a network can be very simple; but selection of the wrong technology could lock you into a very expensive disaster in the long term. So how should you design your network and select the technology to use? Certain things are fixed, such as the geography of your company. So the network has to fit the buildings. Usually you end up with a mix of technologies, usually defined as local area networks within the buildings and wide area networks between distant sites.

Network standards

If you read the computer press, you will see hundreds of branded network products. But essentially these fall into two camps – those that are designed to conform with the international standard for networking, the OSI Open Systems Interconnect model (OSI), and those that are pure proprietary networks. The latter encompass a range of low-speed PC networks together with products for interconnecting peripherals such as terminals and printers. Because these are proprietary, by definition they are heading rapidly into the obsolescence bin.

OSI specifies a number of interconnection technologies, i.e. the glue with which networks can be physically built.

X.25 is a wide area technology best known as packet switching. In the UK it is offered as a public data network service by British Telecom as PSS (Packet Switch Stream). Mercury Communications offers similar services.

IEEE 802.3 (or to give it its ISO title, IS 8802/3) is a standard derived from, and compatible with, the original ethernet standard developed by DEC, Xerox and Intel, introduced in 1980. Ethernet technology dominates the local area network marketplace, with about 70% of installed networks being based on ethernet. It is a non-proprietary standard used by a great number of computer system vendors, as well as the three developing companies.

IEEE 802.4 is a standard for a token-passing bus technology. The most well known implementation is the MAP (Manufacturing Automation Protocol) used in some factory environments.

IEEE 802.5 is the standard based on IBM's Token Ring technology, introduced in 1985.

Choosing the technology

The majority of networks are used to interconnect multiple sites, with many computer systems on each site. A single site can be regarded as a sub-set of this, although we would hope that all successful companies eventually grow into multiple sites! So the basic topology is one of local area networks interconnected with wide area links. Since the choice of wide area services is defined by the public suppliers the major decision is which lan technology to adopt.

IEEE 802.4 MAP style networks are really limited to specific factory applications, whereas the bulk of the market place is looking for networking for the commercial and office environment.

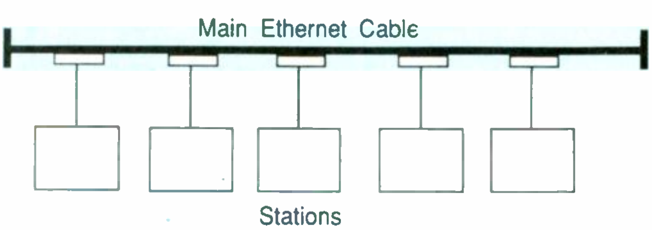
So the choice reduces to ethernet or token ring. To compare these two technologies, we must look at specific areas, but first let us describe the basic technology.

Ethernet

Ethernet is a bus technology, with all devices attached to a single piece of wire. In its simplest form, this is an unbroken length of coaxial cable. The computers attach by clamping on to, but not breaking, this cable. This extremely simple design results in very high reliability, since the only common component is the cable.

Since all devices have equal access to the physical cable, there has to be an arbitration scheme. This scheme is called CSMA/CD (carrier sense multiple access with collision detection). All devices have equal access and wait for a clear period on the cable before transmitting. Where two or more stations start transmitting simultaneously, there will be a collision and both stations will wait a short random time before re-transmitting.

Because devices all have access to the cable, only active devices actually participate in the network. Devices can be added or removed on a live network with no disruption, since the cable is not broken.



Simple ethernet topology.

Token ring

IBM's Token Ring differs at a very basic level, in that the arbitration scheme used is that devices are not free to transmit when they wish: rather, they have to gain the right to transmit. This right is in the form of a token which is continually passed around the network, a continuous ring.

Each station on the network is an integral part of the cable, with all signals passing into and out of it. Each station must take all incoming data and retransmit it to the next station. When the token is received by a station, it decides whether to use it or not.

To allow for errors and the reconfiguration of the ring, there must be a network master (or masters), which ensures that the token is kept circulating and re-starts the network in the case of failure or loss of the token. Token rings are extended by interconnection of separate rings, so as to limit the maximum number of stations, and hence the propagation delay, of the token.

LAN performance

This is the area which is promoted most: basically, "My network is faster than yours" advertising. Like comparing computer systems, where all the argument revolves around Mips and benchmarks, raw numbers are a poor indicator of system performance.

The basic numbers are that ethernet propagates signals at 10Mbit/s and IBM Token Ring at 4Mbit/s, with 16Mbit/s available in the future. Some proprietary token passing systems clock signals at up to 10Mbit/s. This is not the real story. Both networks support many attached systems, all of which may be trying to use the network for different things. So what performance can any one system get from a network and how many systems can simultaneously use the network?

The time taken for a data packet to reach its destination varies linearly with a number of factors, whilst the network is loaded below a certain threshold. Above that threshold, network performance drops off dramatically, with maximum network throughput some way below the maximum network speed.

On an ethernet, the propagation delay varies with the overall length of the network, but not with the number of attached nodes. Also the network overhead varies with the size of packets, smaller packets carrying more overhead per byte of data. As the load rises, as expected, each station is more likely to have to wait for the cable to be clear before transmitting; and there are more collisions, so the delay rises linearly with load. This continues until the knee is reached when multiple collisions are regularly occurring and many stations are waiting to transmit.

On a token ring, the propagation delay depends on the number of stations in the ring, since each station has to pass the token, whether or not it has any data to transmit. This leads to the situation where even if only two stations wish to be active on a ring, they have to suffer the propagation delay of token passing through all other stations. In a similar way to ethernet, delay rises linearly with load until so many stations wish to be active that the token is taken at each station it reaches, and the time taken for the token to traverse the whole ring becomes large.

There is a solution. The solution for both ethernet and token rings is to break the network and hence the workload into smaller sub-networks and to link the sub-networks with bridges. It is the performance of these bridges which will define the absolute performance of the network.

Bridges

Because the bridge learns the topology of the network, it is able to make decisions about network packets that arrive at it. Where the data destination is on the same side of the bridge as it arrives at, it can be discarded; hence the traffic is kept local to the sub-network. This technique might be used to separate a file server and its client workstations from the rest of the network, thus keeping overall network load down. This technique works well because computer usage tends to follow human patterns, with people interchanging data and sharing resources much more frequently at a departmental or work-group level than with the rest of the company.

Over time, as loading increases, bridges can be inserted at strategic points on the network to solve any load-related problems. It is obvious that the performance of the bridge is critical to the overall network performance, since the bridge must be able to process all the packets that arrive in real time and forward, with minimum delay, some subset of them.

Network growth

We have already considered the network's response to increasing load, but what of its physical growth? What are the limits?

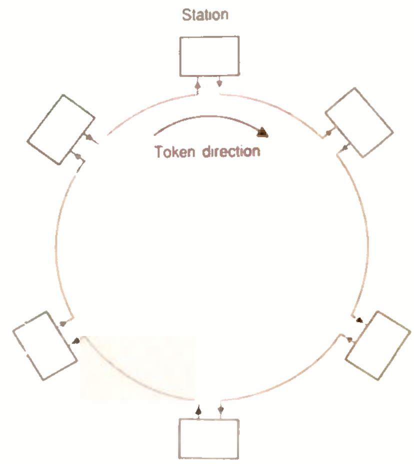
A single ethernet segment can support up to 1024 attached devices and this can be grown by extending the network with bridges to over 8000 stations. There is no advised maximum attachment since adding stations physically does not affect network performance.

The station limit on token ring depends on the cable used. For the simplest twisted-pair cable at 4Mbit/s the station limit is 72 stations, but configuration guidelines suggest about 30% of this (20-30), to avoid excessive delays in token passing. For higher quality cables the station limit is 260. Beyond these figures the ring must be grown by bridging to another, separate ring.

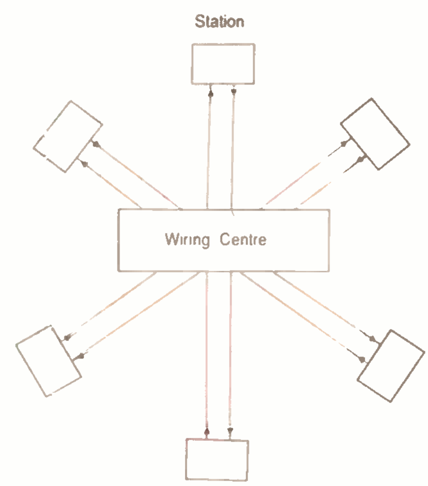
Ethernet's great advantage over token rings is that no station relies on any other. Stations can be added and taken away at will. In fact even new attachments can be made to the ethernet cable, whilst the network is live, without affecting performance. On joining an ethernet, a station may choose to broadcast a regular status message, from which other stations may build up a database of active stations, but there is no absolute need to do so to maintain network integrity.

On the other hand, on a token ring, the integrity of the ring must be maintained at all costs. Adding a station involves breaking the ring; and even if this is transient, the configuration databases must be updated before the ring can continue processing. Similarly, if a station fails, the ring must bypass it physically to maintain the ring.

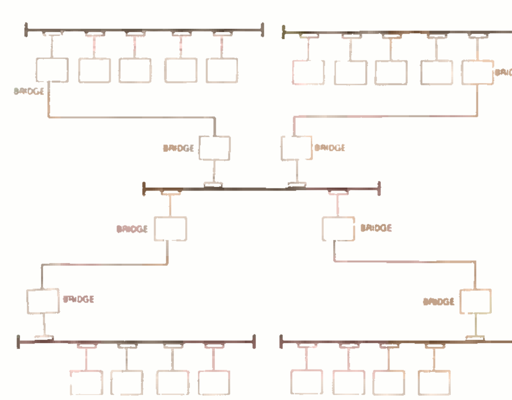
In summary, ethernet has a don't care, open approach to re-configuration and growth, whereas token ring has a closed and controlled method. ■



Simple token ring.



Token ring wiring technology.



Meshed ethernet technology.

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R F COMMENTARY

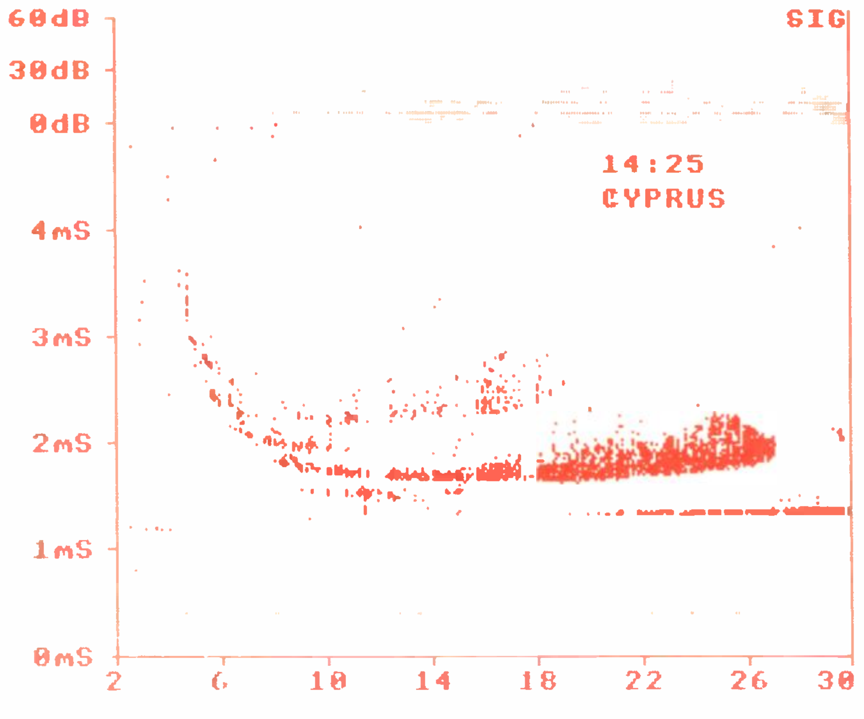
Adaptive HF management

The dramatic increase in traffic throughput achieved in two large UK defence systems by the use of automatic frequency-adaptive control systems is encouraging the Electronic Engineering Association's HF Communications Committee to press forward with proposals for the establishment by the ITU of a number of "common pools of channels" in the international table of HF frequency allocations. They foresee the possibility of two types of licences being issued for civilian point-to-point services: one comprising common blocks of frequencies (akin to amateur radio band allocations) in which adaptive systems would be permitted to find and use free channels; the other form of licence would remain similar to existing practice where users are allocated a small number of specific channels and are not authorized to shift frequency to dodge interference.

At a recent IEE colloquium, "Adaptive HF management", a paper by G.K.L. Smith and R.J. Goodwin, representing the EEA committee, defined an HF adaptive system as "one which automatically (i.e. without the necessity of intervention by an operator) carries out the functions of establishing the communication link(s) and exchanging the message(s) in an optimum manner despite the variations in propagation conditions and the high probability of interference inherent in the HF band".

In support of block allocations, EEA points to the experience of two UK automatic systems using the relatively large number of channels available for defence purposes – the Plessey AiCORN system now in use for the Home Radio Defence System (HRDS) project and the Marconi ASSATS (automatic ship-to-shore channel-selection and telegraph traffic-handling system). It is claimed that these systems have shown that traffic density has been dramatically increased relative to earlier non-adaptive systems: "Improved efficiency is apparent in the better utilisation of station equipment through shorter message transmissions achieved in terms of less need for queueing whilst awaiting favourable propagation conditions and in less 'on air' time".

Above: example output from the Hull MUF measurement system. Solid bars in the 'Chirps' columns represent a chirp occurrence in the channel. 'Interference' is the value logged on the pre-scan. Propagation here is patchy between 6 and 18MHz. Below, for comparison, is the output of a traditional chirpsounder, which compares well with the Hull results. These comparative trials were performed at RAE Farnborough with both receivers connected to the same antenna.



EEA believes that, although further study is needed, "block" segments of spectrum for adaptive working could be introduced into existing allocations without necessarily increasing interference to existing users since adaptive systems would not choose to transmit on busy channels. It is pointed out that (as amateur users of "shared" bands can confirm) interfering stations seldom check whether a channel is already in use before starting to transmit! Adaptive systems might also decrease the time spent by point-by-point services in "idling" on channel to discourage other users. Adaptive channel-selection systems for commercial operators would, in effect, bring them into line with amateur practice over the past 40 years. Amateurs largely abandoned fixed (crystal-controlled) channels in favour of VFO operation, manually searching for free channels and often sending QRL? ("is this frequency busy?") before transmitting a CQ call.

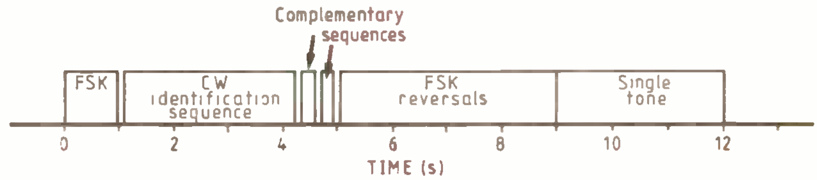
The ten-paper IEE colloquium also included contributions from the Universities of Hull and Warwick which together have formed the Hull-Warwick Communications

Research Group. The morning papers were concerned with frequency management including the increasing use of chirpsounders and adaptive systems. The afternoon session was concerned with coding and modems including performance details achieved with computer-simulation tests of the 4800bit/s serial HF modem developed at Loughborough University of Technology using band-limited quaternary phase-shift keying.

Currently over 40 listed chirpsounder transmitters are located throughout the world; they are capable of being used to obtain real-time ionograms to enhance the accuracy of propagation predictions made using an automatic HF frequency management system. Unfortunately the reception equipment for this system currently costs in the region of £50 000 so that it is not cost-effective to incorporate such equipment directly into automated systems, in which the cost per terminal might be of the order of £10-20 000. Tony Jowett (University of Hull) described a relatively cheap alternative based on a TMS320C25 matched filter board attached to a Personal Computer clone to provide a combined display of detected chirps and interference on a series of channels spaced at 200kHz intervals (illustrated opposite, top of page). Apart from its use to enhance the performance of automatic systems, the technique, it is suggested, could be useful to those unable to employ active RTCE (real time channel evaluation) systems.

HF beacons

At the Adaptive HF Management colloquium, Professor Mike Darnell (University of Hull) gave further information on the ambitious plan to set up a global network of HF (2–30MHz) transmitters and receivers that will enable a wide range of users (including radio amateurs) to monitor and collect a variety of real-time data on HF propagation and noise/interference conditions (see "HF propagation study", *E&WW* February 1989, page 202). It is hoped that the first two or three beacon transmitters will be in operation by about July and the system should then progressively build up to nine or ten transmitters. The motivation for this plan, as proposed by Les Barclay (DTI), is to provide CCIR with an enhanced data base for HF broadcast planning. Transmitter frequencies will be in the fixed service allocations, close to HF broadcast bands near 5.5, 8, 11, 15 and 20MHz. For a nine-transmitter network, each transmitter would cycle through the same five frequencies in a 20-minute sequence, transmitting three 12-second samples on each frequency (see diagram, above, right). There would be 45 components radiated in each 20-minute interval, requiring two receivers in parallel to monitor all components four times in this period. A trial system using just two UK transmitters (9915kHz and 12 040kHz) was



Format of the 12-second beacon signals from the real-time-channel-evaluation (RTCE) system to be based on an HF network. This is due to become operational progressively from next July on frequencies near 5.5, 8, 11, 15 and 20MHz and will be suitable for automatic or manual use.

demonstrated at Geneva in May 1988. While both transmitters and receivers will be automated, it will remain possible for amateurs to derive some useful information on the real-time propagation conditions.

A simple HF beacon system has been operated by the USSR for many years, and I have always found the two or three beacons often audible on about 20 993kHz a very useful indication of propagation conditions on the 21MHz amateur band. Each transmitter radiates a "single letter" Morse symbol and such beacons have been reported at times on many other frequencies from 3 to 21MHz. According to the latest edition of Guide to Utility Stations (7th edition, Klingenfuss Publications), which gives frequencies and locations, the locations include: B, S Archangel; C, O Moscow; D Odessa; F Vladivostok; K Khabarovsk; L Leningrad; M Magadan; P Kaliningrad; U Kholmsk; Z Mukacheva. X in this series is given as Prague, Czechoslovakia, the only beacon listed outside the USSR.

Pioneers no longer?

Recently in giving a talk to a Surrey amateur radio society I could not help noticing that although the meeting had attracted a sizeable audience, few of those present were under 35 years of age, and the majority will not see 50 again. Afterwards I enquired whether this was representative of the society's membership and was told that recent attempts to attract more younger members had proved unsuccessful. It seems to be part of a global pattern, with relatively few teenagers now seriously interested in amateur radio as a hobby. Those that are show little interest in local activities.

Some suggest that the ability to communicate from home with other enthusiasts over long distances has lost its appeal to a generation served by international direct-dialling telephones, with transportable satellite terminals bringing vivid news pictures from Afghanistan into the home, and where many youngsters now expect at some time to see for themselves those remote places with which an occasional radio contact was once an exciting event. Radio communication seems to have lost much of the unique glamour that once surrounded it, although still retaining its appeal to those who have lived through so much technological change in this field.

In the USA, efforts to interest the young often revolve around a plea to introduce a licence not subject to Morse tests. Such licences, widely available in Europe for VHF-only since the 1960s, certainly led to significant growth for a time but this seems not to have been sustained.

A Californian amateur, Harry Helms, AA6FW, in a letter to *Ham Radio* (February 1989) points out that the ageing of the hobby is itself a discentive: "Would you (as a teenager) want to talk to a bunch of people old enough to be your grandfather? I'm 35 and have a hard time finding someone interesting to have a ragchew with. . ." He points out that, although few existing amateurs openly admit it, many secretly want fewer rather than more amateurs despite the argument that unless very full use continues to be made of all amateur frequency allocations, they could be pared away at future World Administrative Radio Conferences.

One recalls how, in the 1930s, relatively young amateurs pioneered many aspects of the technology, not just for the hobby but also for professional communications. Small firms set up by amateurs to cater for their own market soon became established leaders with the wartime expansion of the radio communications industry.

Arthur Collins, W0CXX, formed Collins Radio to build a range of transmitters for the amateur market; Bill Halligan, W9WZE, formed Hallicrafters to build low-priced communications receivers; in the UK, Eddystone Radio in the mid-thirties under Harold Cox and Arthur Edwards, G6XJ, concentrated on HF receivers for the tropics (pioneering tropicalization) and component parts for amateurs.

The death in late February, at the age of 81 of Bill Eitel, W6UF, is a reminder of how in 1934, at the age of 26, he joined forces with Jack McCullough, W6CHE, to form, with a $5000 stake, the firm Eitel-McCullough Inc. (Eimac) to manufacture RF power valves for amateur transmitters. Eimac's products were soon used also for commercial and military transmitters – and later gained a major role in television broadcasting, satellite links etc. In 1965 the firm, which then

R F Commentary

had a work-force of 1800, merged with Varian Associates and became their Eimac division, headed by Bill Eitel until his retirement in 1974. Throughout his working life and retirement he continued to encourage amateur radio. The Eimac club helped pioneer amateur "moonbounce" (EME) and in 1965 he played a key role in "Project Oscar" to launch amateur radio satellites. Even after his retirement he installed a well-equipped laboratory at his retirement home in Nevada, making further useful inventions.

Meteor scatter

Over thirty years ago, the then *Proc.IRE* (December 1957) devoted a special issue to communicating by means of meteor scatter propagation, a concept that can be traced back to a note by G.W. Pickard on the relationship between meteor showers and radio reception in *Proc.IRE* (July 1931). A good deal of experimental work, particularly during the 1950s, was carried out using high-speed bursts, during the periods when the short-lived ionized trails from meteors result in paths opening over distances up to about 2000km intermittently for short periods – usually less than a second duration but occasionally for a few seconds. It was shown that an average throughput of a few words per minute could be achieved consistently at all times.

But with so much interest in the 1960s and 1970s concentrated on satellite communications, interest in meteors waned for professional communications, although the mode continued to be used by some radio amateurs during the regular meteor shower periods when paths open more often for the longer periods.

Recently interest has revived and it is now confidently expected that during the next few years a number of modern meteor communication systems will add to the few already operational for both civilian and defence applications. In a tutorial paper "Meteor scatter: an overview" (*IEEE Trans. Ant. & Prop.* December 1988, pages 1813-19), Dr Jay Weitzen and William Ralston (University of Lowell, Mass.) suggest that the revival of interest in both HF and VHF meteor scatter communications is due to such factors as the recently perceived vulnerability of satellite-based systems, coupled with the availability of inexpensive microprocessor-based control systems. Both HF and meteor-scatter can provide survivable back-up to high-throughput systems, and are also suitable for remote sensing. Meteor scatter has the advantage over HF in that it does not depend on variable ionospheric reflection, can work on a single frequency with less complex control and is free of the problem of a varying skip zone (with suitable antenna patterns and link protocols, paths can be established over all distances up to the single-hop E-layer maximum of about 2000km). The disadvantage is the low average data rate and the short gaps between transmissions. The authors also point out that frequencies between about 40 and 100MHz are less subject to polar cap absorption and the frequent HF blackouts at high latitudes, while the relatively small "footprint" from a meteor trail provides a degree of protection against interception and/or jamming.

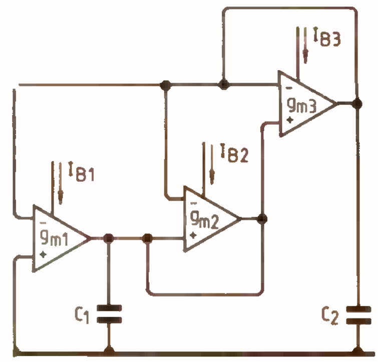
Both RAE and the Royal Signals have been experimenting with computer-controlled meteor scatter systems (*E&WW* November 1988, page 1135 etc.), achieving average data rates of 20-25bit/s. The US Air Force at its high-latitude test-bed between Anchorage and Bethel in Alaska has shown (*IEEE Trans. Comms.* August 1984) that data rates can be increased by a factor of ten with adaptive systems that adjust the data rate to the capacity of the channel for a given bit-error rate. Multipath problems can be experienced during sporadic E conditions and also from auroral scatter which is important at high latitudes.

● See also "A new meteor logging technique", page 540.

Simpler OTA-C oscillator

The August 1987 *E&WW* (pages 794-796) introduced a number of novel sine-wave oscillators stemming from work at the University of Bahrain. One was an electronically tunable active-C oscillator requiring no resistors and based on operational transconductance amplifiers (OTA) rather than the more commonly-used op-amps. The 1987 OTA-C oscillator used a chain of five OTAs and two earthed capacitors, with a near-linear variation of frequency from 5 to 50kHz achieved by varying the direct bias current. Other workers have described OTA-C oscillators using four OTAs.

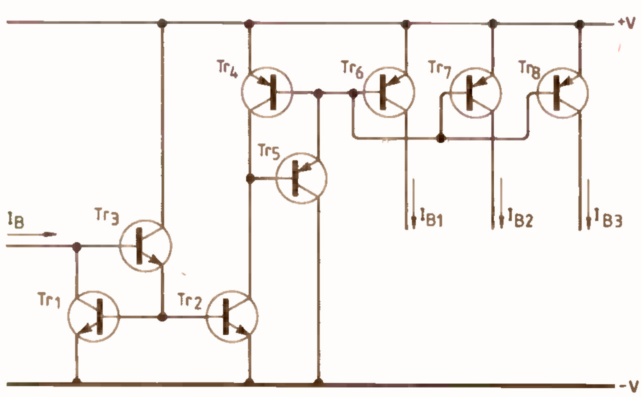
A simplified form of OTA-C sinewave oscillator, using only three OTAs (illustrated above), has been described by R. Senani at the Delhi Institute of Technology in *Electronics Letters* (February 16, 1989, pages 286-7). It is pointed out that circuits which consist of only OTAs and capacitors provide several attractive features not possible with conventional op-amp-based circuits, including linear electronic tunability of parameters over a wide range by varying an external current or voltage, as well as greater suitability for IC implementation as a result of the elimination of external passive resistors.



OTA-C electronically tunable sinewave oscillator developed by R Senani (*Electronics Letters*).

To achieve variation of frequency without disturbing the condition of oscillation, previous OTA-C oscillators have used four or five OTAs and more than two capacitors, or alternatively have included passive resistors. The circuit shown above meets the required conditions with only three OTAs and two earthed capacitors. Condition for oscillation: $g_{m3} - g_{m2} = 0$ with $C_1 = C_2 = C$ and $f_0 = (g_{m1} \cdot g_{m3})/(2\pi C)$.

R. Senani also provides an integratable circuit to provide simultaneous variation of the direct bias current for the three OTAs (below) by variation of a single external current.



Circuit permitting simultaneous variation of the bias currents for the three OTAs.

RF Commentary is written by Pat Hawker.

“Optical” techniques for microwaves

At sub-millimetre wavelengths, waveguide exhibits large losses. Quasi-optical techniques, using collimated beams of radiation, avoid the problem

RACHAEL PADMAN

The region of the electromagnetic spectrum between about 100 GHz (λ = 3 mm) and 1000 GHz (λ = 0.3mm) has become increasingly important over the last 10-15 years. Originally, the only detectors available for this frequency range were bolometric, or *incoherent* detectors, similar to those in use in the infrared wavebands. More recently, however, applications as diverse as astronomy, molecular spectroscopy, plasma diagnostics, high-resolution imaging and secure communications have generated requirements for high spectral resolution and/or high time resolution, which can only be achieved by the use of heterodyne (*coherent*) techniques, with a concomitant increase in the complexity of systems. All the standard microwave-type components such as filters, attenuators, couplers, terminations etc. are required, in a frequency range where the standard waveguide may have typical dimensions of less than a millimetre – for example, WG32 (WR3), which nominally covers the band from 220 GHz to 325 GHz has standard dimensions of 0.87 mm × 0.44 mm. At these frequencies even the very best waveguide could be expected to have an attentuation in excess of 10dB/m based purely on considerations of skin-depth: practical waveguides often have attenuations somewhat higher than this.

Waveguide propagation therefore is subject to considerable losses. Because of the very short wavelengths involved, however, it is instead possible to produce well collimated *beams* of radiation which propagate in free space, and only occasionally need to be refocussed by lenses or mirrors. Because of the close similarity of such systems to those of conventional optics, the name *quasi-optics* has been coined to describe applications of optical techniques to the far-infrared and millimetre/submillimetre wavebands. With careful system design it is possible to keep the losses down to the level of a few percent or less in any leg of the optical path. Components for quasi-optical systems generally have dimensions characteristic of the beam diameter, making them easier to manufacture than their microwave counterparts at the same frequency.

Of course, the idea of using optical components at microwave frequencies is not new – the parabolic dish antenna is an early example of a design lifted directly from traditional optics, while lenses were also discussed in the late 1940s[1]. However, two factors have combined to give the field of quasi-optics the prominence it enjoys today. The requirement for complex, low-noise (and hence low-loss) millimetre-wave heterodyne radiometers and spectrometers – as outlined above – provided the push, while the pioneering work on Gaussian beam-modes at Bell Labs in the mid 1960s provided the mathematical foundation which allowed relatively easy calculation of coupling and loss factors. In the rest of this article we will briefly review the characteristics of such Gaussian beams and then look at some common quasi-optical components, comparing them with their microwave analogue.

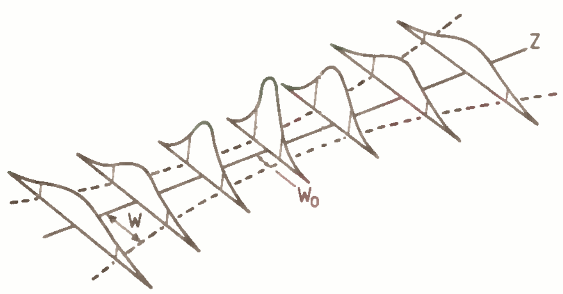


Fig.1: Propagation through a waist of a fundamental mode Gaussian beam. The intensity distribution along any cut perpendicular to the propagation axis is a Gaussian function of the distance from the axis (Adapted from Fig. 2 of reference 3).

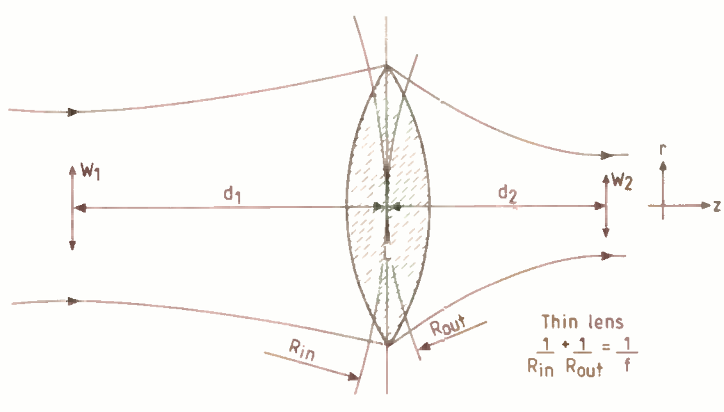


Fig.2: Re-imaging with a quasi-optical lens. Ncte that the radii of curvature R of the incoming and outgoing beams are not necessarily equal to the distances of the beam-waists from the lens.

FUNDAMENTALS OF GAUSSIAN OPTICS

Although we can, of course, apply a full electromagnetic diffraction analysis to the problem of wave propagation in quasi-optical systems, the costs in development and computer time would be prohibitive for all but the largest systems. Early work on laser resonators[2], however, showed that *beams* of radiation obeying certain, not very restrictive symmetry conditions could be represented as sums of orthogonal beam modes, in much the same way as the set of fields in a waveguide can be decomposed into transverse electric (TE) and transverse magnetic (TM) modes. For beams with axial

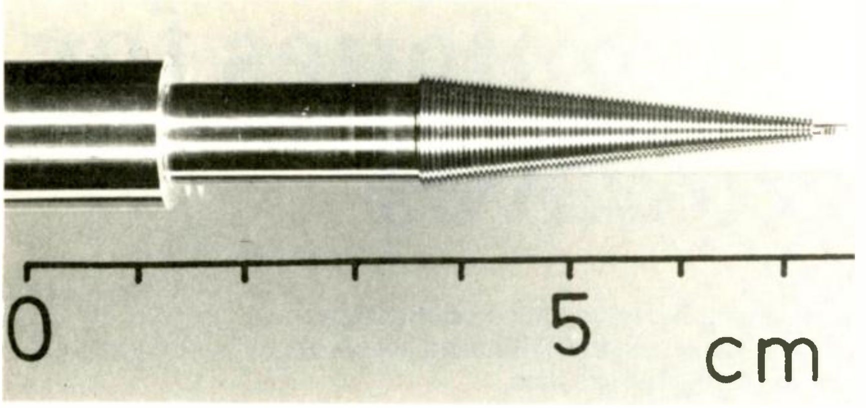


Fig.3: Aluminium mandrel for a corrugated scalar horn for 270 GHz. The horn is produced by electroforming copper over the aluminium, and then etching away the mandrel using sodium hydroxide solution. The aluminium mandrel is therefore a solid "negative" of the inside of the final horn. The corrugations in the horn help to produce a more circularly symmetric beam pattern than can be obtained with a simple smooth profile. Note the detailed machining of the low-loss mode transducer at the throat of the horn, where rectangular waveguide is converted into circular waveguide.

(cylindrical) symmetry the natural expansion is in terms of the so-called Laguerre-Gauss functions, while beams with symmetry about the planes $x = 0$ and $y = 0$ can be expanded in terms of Hermite-Gauss functions.

We imagine a beam propagating along the z – axis away from the *beam waist* – that is, the plane in which the beam has minimum spatial extent and zero radius of curvature (see **Fig 1**, taken from reference[3]. The *fundamental*, or lowest-order mode is identical for both sets of modal expansions: at every plane such that *z = const* the electric field intensity is a gaussian (bell-shaped) function of the transverse distance r from the propagation axis. That is:

$$\xi(r) \propto w(z)^{-1}.\exp\{-r^2/w(z)^2\}. \qquad (1)$$

The beam is completely defined by the beam radius w and the radius of curvature of the wavefront R which these depend on z and λ as (see reference 4):

$$w(z) = w_0(1 + (z/\hat{z})^2)^{1/2}$$
$$R(z) = z.[1 + (\hat{z}/z)^2] \qquad (2)$$

where w_0 is the *waist radius*, and the *confocal distance* $\hat{z} = \pi w_0^2/\lambda$. Note that w(z) is the *field* radius – i.e., the distance from axis at which the field strength drops to e^{-1} of its value on the axis: at this point the relative *power* is e^{-2}, or 8.7dB.

To compare these results with those for conventional optics, observe that in the so-called geometric optics limit, as $\lambda \rightarrow 0$, the confocal distance, associated with a waist radius w_0 much *greater* than λ is very large, and from equation (2) we see that the radiation propagates as an apparently parallel beam for very large distances before diverging. On the other hand, if w_0 and λ are both very *small* compared with the dimensions of the optical system being studied, the beam appears to diverge from a point-like focus – here the beam diameter grows linearly with z and the radius of curvature of the beam, R(z), is everywhere equal to the distance z from the focus. Thus Gaussian-beam optics reveals the existence of *three* regimes, depending on whether $z/\hat{z}$ is $\gg 1$ (linearly growing beam), $\ll 1$ (parallel beam) or somewhere in between. Many millimetre and submillimetre wave systems fall into this grey in-between area, requiring us to use the formulae (1) or (2) for design purposes, rather than the simple formulae of geometric optics.

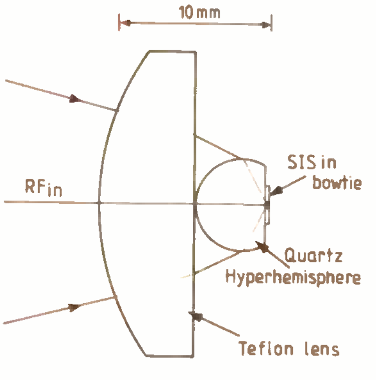


Fig.4: Bowtie antenna on quartz hyperhemisphere. (From M.J. Wengler, D.P. Woody, R.E. Miller and T.G. Phillips, "A low noise receiver for millimetre and submillimetre wavelengths", in *Int'l J.IR and mm Waves*, vol. 6, No.8 Aug. 1985 pp 697-706)

If a beam consisting of just a fundamental (pure gaussian) component is to propagate unhindered, then the diameters of all optical components should be at least four times the beam radius at that point – otherwise the truncation will produce sharp edges on the beam and scatter energy into higher order modes. For many purposes it is possible to consider only the fundamental mode, and in the interests of simplicity we ignore the higher-order modes in the following sections. It should be borne in mind, however, that when the beams *cannot* be well described by a simple gaussian alone, then the higher-order modes must be included in any calculation for maximum accuracy[5].

FOCUSSING COMPONENTS

Lenses and mirrors are used as focussing components in exactly the same way as for conventional optics. The beam radius of curvature, R(z), however, is not equal to the distance z from the beam-waist, or focus, except for very large values of z. It is therefore necessary to use R rather than z itself when calculating the required lens or mirror focal length. For example, the familiar optics formula:

$$1/f = 1/d_1 + 1/d_2 \qquad (3)$$

becomes

$$1/f = 1/R(d_1) + 1/R(d_2) \qquad (4)$$

where d_1 and d_2 are the distances from the lens of object and image respectively (see **Fig. 2**) and R(d) is the radius of curvature of the gaussian beam at distance d. Since R depends on the wavelength, lenses and mirrors for quasi-optical applications are generally *not* wavelength independent.

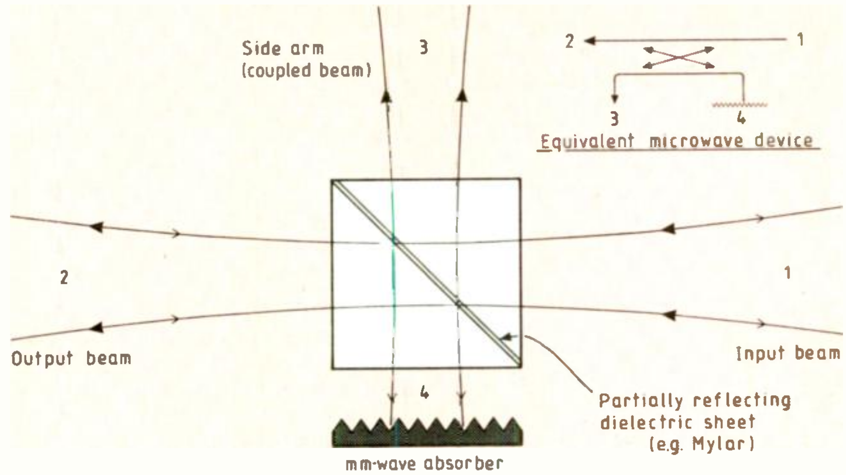
Many dielectrics have been used to make lenses at millimetre wavelengths, including various plastics, such as PTFE, high-density polyethylene (HDPE), Rexolite (a cross-linked styrene polymer) and TPX (Poly-4-methylpent-1-ene), as well as high refractive index materials such as quartz. The latter, however, require blooming if reflections from the surfaces are to be reduced to an acceptable level. All dielectrics also have some absorption loss at these frequencies, which generally increases with increasing frequency.

For many applications mirrors are preferred as focussing elements. These are normally machined to the required paraboloidal or ellipsoidal shape on a numerically controlled milling machine, and then hand-polished to give a near-optical-quality finish. Mirrors have the further advantage that the optical system can normally be set up and aligned using visible light, whereas most of the dielectrics suitable for mm-wave use are either only translucent, or at best are transparent, but with a quite different refractive index (TPX is an exception, in that its mm-wave refractive index is very close to the value it has in the optical).

LAUNCHERS

Much as we would like to carry out all signal processing in quasi-optical "circuitry", we do from time to time need transducers to convert quasi-optical signals to and from guided waves in waveguide or coaxial line. This is done with an antenna, with perhaps a lens or mirror to provide focussing and keep down the size of the aperture. Fortuitously, it turns out that the species of horn antenna known as the *scalar feed* generates a very close approximation to the fundamental Gaussian mode, with 98% of the total energy carried in the fundamental mode, and most of the rest in the first few higher-order modes. This is thus the launcher of choice for most applications. At submillimetre wavelengths it becomes increasingly difficult to manufacture the corrugated horns required for wideband performance, and smooth-walled dual-mode horns may then be used; these give comparable performance but with very limited bandwidth (≲ 10%). **Figure 3** shows the internal structure of a scalar feed. Other less conventional laun-

Fig.5: A quasi-optical directional coupler, as discussed in the text under "Couplers and filters". Also shown is the conventional symbol for a microwave directional coupler, emphasizing the direct equivalence of these two devices.



chers include the bowtie antenna on a quartz hyper-hemisphere (**Fig. 4**) and the corner-cube reflector[6].

COUPLERS AND FILTERS

One standard configuration for such a structure consists of a thin dielectric sheet placed to make some angle to the beam axis, with the thickness of the sheet determining the degree of constructive interference between reflections from the two air/dielectric interfaces (see **Fig. 5**). If the beam-splitter is *lossless*, and a fraction T of the incident energy is transmitted through the main arm, then it is apparent that a fraction $R = 1 - T$ is reflected into the side-arm. Now, if we consider a signal *arriving* from one of the side-arms, then we can see that a fraction T of this must also be transmitted straight through (since the two arms are identical in every way), and therefore a fraction R is reflected into the main arm. The beam-splitter is thus exactly analogous to a 4-port direction coupler, with coupling coefficient in dB equal to $-10 \log_{10} R$ — values between 6 dB and 20 dB are easy to generate in this way. As an example, a piece of mylar dielectric 12μm thick has a reflection coefficient of about 2% (−17dB) at a frequency of 460 GHz, for 45° angle of incidence (E-field polarized normal to the plane of incidence).

Most filter designs depend on interference between reflections at multiple mismatches. These may be produced by dielectric inter-

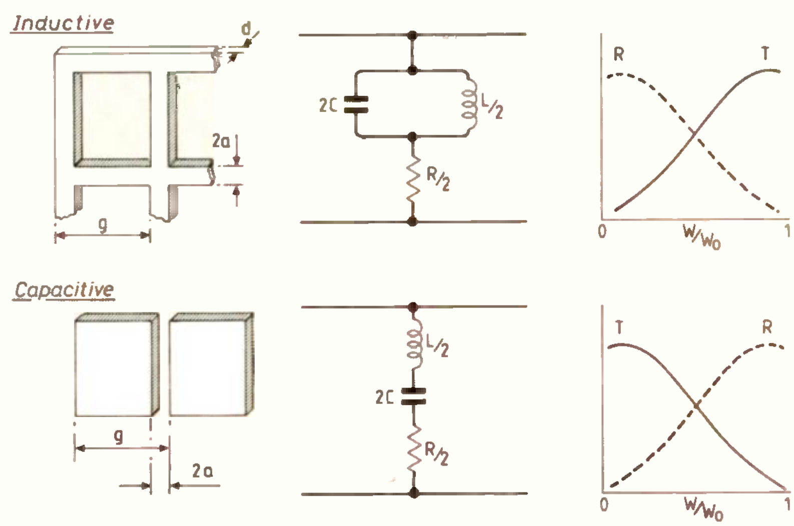


Fig.6: Inductive and capacitative meshes for use as quasi-optical filters or filter elements. Also shown are their lumped element equivalent circuits and their normalized filter transmission curves. (Adapted from C. Cunningham, Ph.D. thesis, University of London, 1982).

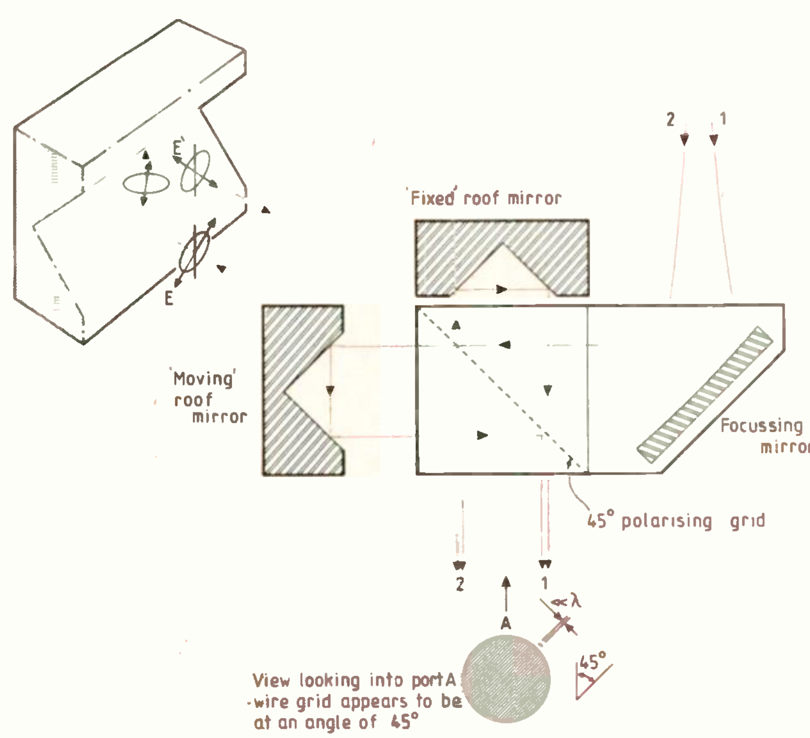


Fig.7: Schematic layout of the Martin-Puplett interferometer shown in Fig. 8. The full ray path is shown only for the beam labelled '1' – the ray path for beam 2 is similar as can be easily verified. The beam is split by the "45°" wire grid into two components polarized parallel to and perpendicular to the mesh. The beam polarizations are then rotated by 90° after the double reflection at the roof mirrors, so that the beam which was reflected from the mesh is now transmitted, and vice versa. The final output of the interferometer depends on the difference in optical path in the two arms, which determines whether the two beams interfere constructively or destructively as they recombine in the output arm.

faces, as in the beam splitter just discussed (in which case the filter structure is identical to the multi-layer blooming on high-quality optical components, such as camera lenses), or more commonly by metallic meshes of various shapes and sizes. Such meshes can be designed to have either capacitative or inductive impedances, depending on whether the principal energy storage is in the electric field between metallic patches, or in the magnetic field around current-carrying strips. If they are spaced at intervals of $\lambda/4$, then all the theory of traditional quarter-wave filters applies. Mesh filters have been constructed for the entire range of frequencies considered in this article – an example is shown in **Fig 6.**

ATTENUATORS

One obvious way to make an attenuator is to make a coupler with a very high coupling coefficient, or alternatively to make a coupler with a small coupling coefficient and interchange the labels of the side-arm and main-arm. Absorbing material can be introduced into the two unused arms of such a device to mop up the unwanted part of the signal. Modifications might include coating the dielectric sheet with a thin layer of conducting material, so that the wave impedance seen by the beam is no longer purely reactive, thus destroying the condition which makes the simple coupler lossless.

SYSTEMS

Many more complicated devices can also be manufactured, some of which have no direct analogy at microwave wavelengths. These are mostly derived from such optical devices as the Michelson interferometer, quartz half-wave delay plates, etc. One of the most versatile such devices is the Martin-Puplett, or polarizing Michelson interferometer[7], which has the form shown in **Fig 7**. This depends for its operation on the fact that a wave polarized in the 45°-plane will have its polarization rotated by 90° on reflection from a roof mirror. A beam which is initially reflected from the polarizing grid will therefore be transmitted when it returns, whereas the initially transmitted beam is now reflected. The output in each polarization then depends on the relative phases of the two beams recombining at the grid. Martin-Puplett interferometers have found widespread use in the construction of receivers for millimetre-wave astronomy, as local oscillator diplexers, single-sideband filters and LO noise filters. Tandem versions have been built to get more bandwidth than is possible with a single filter (this is essentially the same as using two coupled cavities to increase the bandwidth of a filter). An example of a dual-polarization Martin-Puplett interferometer for frequencies in the range 220-280 GHz is shown in **Fig. 8.**

In an article of this length it is unfortunately impossible to cover all the quasi-optical devices which are of use in the construction of systems for the millimetre and submillimetre wavebands. In addition to the types of device outlined above, there are many more, including now the first non-linear devices such as the quasi-optical frequency doubler, which uses an array of diodes arranged in a mesh much smaller than the beam. Intensive work is now going on in a number of laboratories worldwide to produce integrated quasi-optical structures, in which devices such as superconducting detectors, filters and IF amplifiers are all integrated on a single substrate with a planar beam launcher for coupling to quasi-optical beams. In future, we can expect to see the use of quasi-optics extending to somewhat lower frequencies, with more sophisticated techniques also being applied at the very highest frequencies of interest as the art of making the various components advances.

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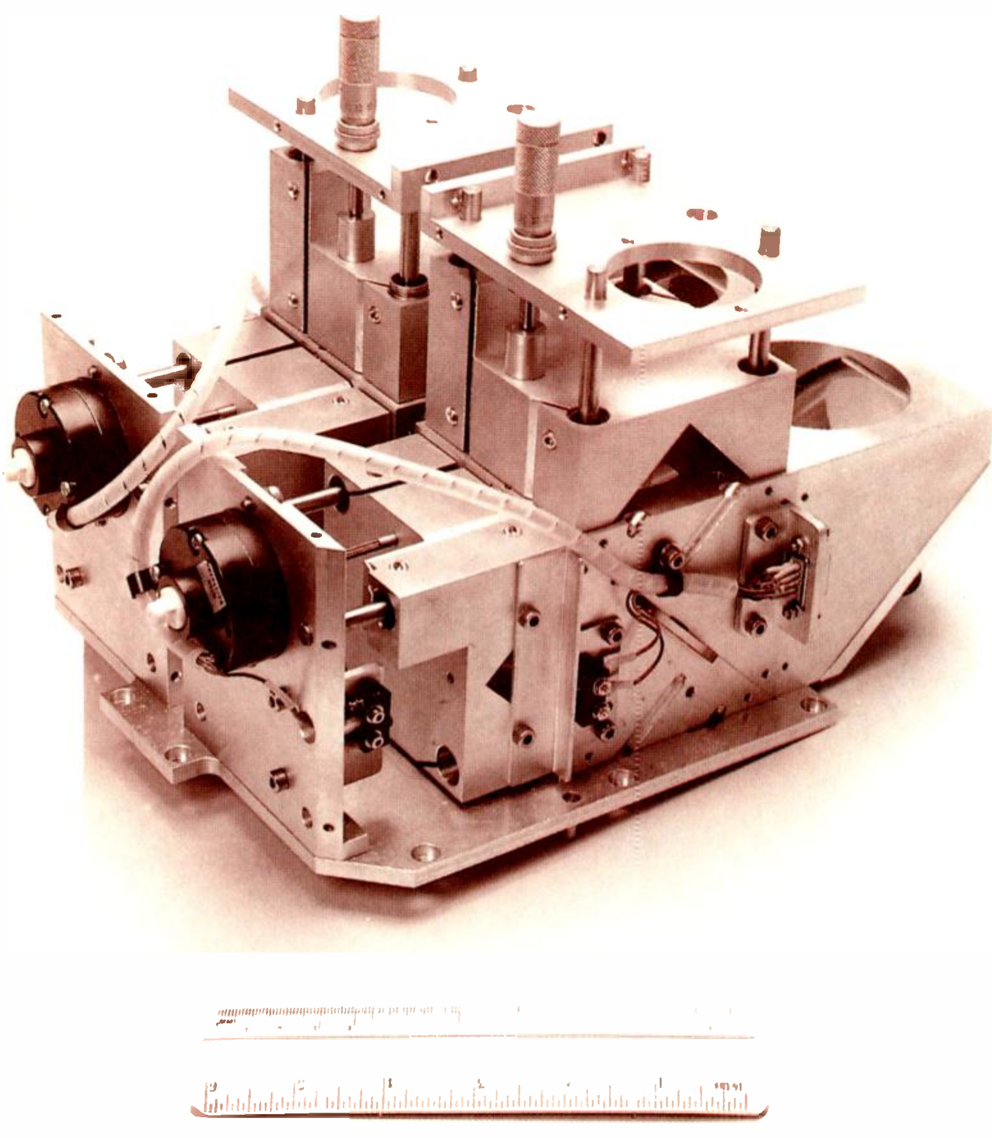
Fig.8: Photograph of a dual-polarization Martin-Puplett interferometer for use in the 220-280 GHz receiver of the James Clerk Maxwell Telescope, on Mauna Kea, Hawaii.



References

1. S. Silver (ed). "Microwave antenna theory and design" New York. Dover, 1965.
2. H. Kogelnik and T.Li, "Laser beams and resonators", *Proc.IEEE.*, vol. 54 pp 1312 1966.
3. D.H. Martin and J. Lesurf, "Submillimetre wave optics", *Infrared Phys.* vol. 18 pp 405-412 1978.
4. P.F. Goldsmith, "Quasi-optical techniques at millimetre and submillimetre wavelengths", in *Infrared and Millimetre Waves* vol. 6, K.J. Button (ed), pp277-343, New York, Academic, 1982.
5. R. Padman, J.A. Murphy and R.E. Hills, "Gaussian mode analysis of Cassegrain antenna efficiency", *IEEE Trans. Antenna. Propagat.* vol. AP-35 pp 1093-1103 Oct. 1987.
6. H.R. Fetterman, P.E. Tannenwald, B.J. Clifton, C.D. Parker, W.D. Fitzgerald and N.R. Erickson, "Far-ir heterodyne radiometric measurements with quasi-optical Schottky diode mixers", *Appl.Phys.Lett.* vol. 33 pp 151-154 Jul. 1978.
7. D.H. Martin and E. Puplett, "Polarized interferometric spectroscopy for the millimetre and submillimetre spectrum", *Infrared Phys.* vol. 10 pp 105-109 Mar. 1970.

Dual buses for industrial I/O – 2

Continuing the discussion of dual-bus computer systems, Jeremy Bentham of Arcom Control Systems examines the software aspects

A considerable mystique has grown up about the method of driving I/O cards in high-performance systems such as VME. Most manufacturers provide a software 'driver' to go with their boards, for interfacing to the operating system. Whilst this approach has the great advantage of insulating the user from the harsh realities of real-world I/O, it can be extremely inflexible: if the driver doesn't quite do what you want, tough luck.

This article describes the steps to take in writing some software to drive an I/O board using the OS-9 operating system on a 68020 processor board. The two main boards under discussion (SPIBB and SPCGA) are on STE-bus, and the processor is the VSC020 dual-bus STE/VME one, since this is the most economical method of providing I/O on small-to-medium systems.

HARDWARE CONSIDERATIONS

The 68000 family of processors use a 32-bit address to access all memory and peripherals, unlike the 8080-type processors which have separate memory and I/O spaces. The manufacturer of a 68000 series CPU board designates which areas of the four-gigabyte address space are to be used for which purpose; the only restriction imposed by the CPU is that the bottom 4K of the address space is reserved for the interruption vector table in ram.

In part 1, Anthony Winter described the way the address space is split up on the VSC020 dual-bus processor, with separate areas for the VME and STEbus interfaces. On the face of it, there is no real difference between programming an STE and VME board; both appear as a series of locations in the CPU address map. The minor differences in access speed are rarely significant in real industrial I/O applications, but the uncomplicated nature of STEbus boards does make them easier to program.

VME bus. The VME bus appears at six different spaces in the 68K address map, depending on the type of VME board being handled. I/O boards are generally of the 'A16' type, that is to say that they take in a 16-bit address value from the bus. Memory boards, on the other hand, often require a 32-bit address. In order that the CPU hardware might determine whether a 16, 24 or 32 bit address is to be put onto the bus, the bus space appears several times in the CPU's memory map. Thus, assuming the VME board appears at bus address 0, a CPU address of $7F800000_{16}$ would be used if it were A16, or addresses of 7D000000, 40000000 for A24 and A32.

```
PROCEDURE spibb
REM OS-9 68020 Basic program to set up SPIBB on STE    JPB 21/2/89
DIM spibb,n:INTEGER
spibb=$7e800fe0
POKE spibb+3,$80
POKE spibb+7,$80
POKE spibb+6,$3f
FOR n=0 TO 65535
   POKE spibb,n
   POKE spibb+1,n/256
Next n
```

Fig. 1. Parallel I/O initialisation in Basic.

Regrettably, the complication does not stop there! VME boards also have restrictions on the data bus width that the CPU can access. A 68020 processor can request an 8, 16 or 32-bit word from a VME peripheral board, yet the device being accessed may only have an 8-bit data bus, for example a simple 8-bit input port. There appears to be no standardisation on the way this is handled: some manufacturers make the peripheral board ignore a mismatched bus transaction, while others pad the data out by the appropriate amount. If in doubt, the programmer must ensure that only 8-bit accesses are made to the board.

The VSC020 CPU board can also make full 32-bit accesses to VME peripheral boards, but normally only memory boards which require very fast transactions use this feature.

One final trap for the unwary: some I/O boards are set to ignore any 'user mode' bus transactions, on the assumption that a user has insufficient privilege to access the board. The CPU has to be in 'system mode' in order that the access may go through. This makes it much harder to write software for the board, since all normal Basic or 'C' programs run in user mode, as does the normal debug utility. One cannot easily create a little program to exercise the board: system mode programming demands considerable extra effort.

STE BUS BOARDS

The two STEbus boards described in this article are a single 32-bit parallel I/O board (SPIBB), and a PC-compatible text/graphics board (SPCGA). A 68020 CPU and PC graphics board may appear to be an unlikely combination, but the SPCGA is handy when 80 × 25 text is required, or simple graphics up to 640 × 256 pixels. The text mode is equipped with the very comprehensive range of PC graphics characters, and is link-selectable to provide standard video output for conventional colour/monochrome monitors, or a high-quality display when used with a high scan-rate monitor such as a multisync. The C code given here will work with the board in either mode, since the increase in scan rate is transparent to the software.

STEbus. Through its inherent simplicity, the STEbus is much easier to use. STEbus has a 1Mbyte memory-address space, and a 4Kbyte I/O address space. These appear at two different base locations on the CPU memory map. Simple peripheral boards appear in the I/O space only. More sophisticated ones may have dual-port ram, and also appear in the STE memory space. For example, the CGA graphics board appears at STE I/O locations 3D0 to 3DF, and the video ram appears at STE memory locations B8000-BBFFF. When accessing this board with the VSC020 CPU, address 7E8003D0 is used to access the base address of the graphics chip, and 7EAB8000 is used for the base of the ram.

Operation of the STEbus is completely transparent to the programmer: the hardware will perform automatic conversion of 16 or 32-bit cycles into the 8-bit ones required by STE. If an attempt is made to access a non-existent board, the CPU receives a 'bus timeout' interrupt.

LOW-LEVEL PROGRAMMING

With a new I/O board, a very useful first step is to send it a few test bytes to confirm the settings and basic operation. It is also very handy to be able to access the board at low-level, while the higher-level software is being developed.

The lowest possible level of access is with the OS/9 User-State Debugger (debug), typing byte strings in by hand. If the board being tested is on VME and operates in system mode only, then the OS/9 System State Debugger (sysdbg) must be used instead. **Figure 2** shows 'debug' being used to set up an STE parallel I/O board (SPIBB) as an output port, and sending test bytes to it. Since the typing of large numbers of 8-digit addresses is tedious, one of the relocation registers in 'debug' has been used to point to the board base address. These relocation registers are purely implemented in software, in an analogous fashion to the hardware CPU registers. Having been set, they can be used as shorthand for the board base address.

USER-MODE PROGRAMMING

Having established that the board is operational by typing hex strings in 'debug', the next stage is to write some simple software to initialise the board. It is most convenient to do this in 'user mode', i.e. as a normal C or Basic program. Since the board appears as a number of addresses in the 68020 address map, accessing it is no different to accessing any memory location in the system.

Basic. OS-9 Basic is a very powerful structured implementation of the language. Direct I/O reads and writes are performed by the standard functions 'peek' and 'poke', using the full 32-bit address as described above (e.g. 7E800FE0 for the SPIBB). **Figure 1** shows a Basic program which initialises a SPIBB and then cycles the binary values 0-65535 out to a 16-bit port.

C language. When programming in C, a pointer needs to be set to the board base address, whereupon accesses can be made as offsets from the base. **Figure 3** is a demonstration program for the CGA text/graphics board, which uses this method for both STE I/O and memory functions. The two I/O functions ('inportb' and 'outportb') use as a base pointer the start of the STE I/O space, 7E800000 hex. The calling function supplies the offset from the base (e.g. FE0 hex), which corresponds to the bus address of the peripheral board.

Memory accesses to the CGA ram are performed by setting a character pointer ('screenb') to the base address of the STE memory space plus the board STEbus address: thereafter, all memory references can be performed by indexing off this pointer. The accesses will be single-byte read or write, since 'screenb' is defined as a 'pointer to char'. To show how wider data transfers are performed, the clear screen function has been implemented using long-word (4-byte) transfers. A 'pointer to long' is set up, and equated to the ram base address. All memory accesses using this pointer will be 4-byte.

```
The SPIBB parallel I/O board must be at base address FE0H

    debug                   Enter debug utility
    .r1 7e800feo            Set relocation reg 1 to base of SPIBB
    @1                      Use relocation reg 1 as default
    c 3                     Change value in register 3 of SPIBB...
    80                      ... to 80H (all ports of IC8 to O/P)
    c 7                     Change value in register 7 of SPIBB...
    80                      ... to 80H (all ports of IC9 to O/P)
    c 6                     Change value in register 6 of SPIBB...
    3f                      ... to 3FH (all buffers to O/P)

Sending sample data to a SPIBB port...

    c 0                     Change value in register 0 of SPIBB...
    aa                      ... to AAH (O/P AAH from IC8 port A)
```

Fig. 2. Using 'debug' to initialise a parallel I/O board.

Fig. 3. CGA demonstration program in C.

```
/* CGA demonstration for OS/9 68020          JPB 30/12/88  */

/* CPU addresses...*/
#define PORTBASE 0x7e800000 /* Base address of STE I/O */
#define RAMBASE  0x7ea00000 /* Base address of STE memory */

/* STEbus addresses...*/
#define CGRAM 0xb8000       /* CGA RAM base address */
#define IR      0x3d4       /* 6845 index register */
#define DR      0x3d5       /* 6845 data register */
#define MCR     0x3d8       /* mode control register */
#define CSR     0x3d9       /* colour select register */
#define SR      0x3da       /* status register */

/* CGA characteristics...*/
#define  LINSIZ 160         /* Number of bytes per line (chars+attribs) */
#define  LINES  25          /* Number of lines per screen */
#define  ATTR 7             /* Normal value of attribute byte */

#define BLANKL 0x20072007   /* Long word containing 2 blank chars
                                 (ASCII spaces with attribute 7) */

/* Global variables..*/^E
^E

int op;                     /* Pointer for o/p to CGA (offset from base) */
char *screenb;              /* Base address of screen RAM */

/* Initialised data... */
unsigned char data[] = {    /* CRTC initialisation for 80*25 text mode */
     0x71, 0x50, 0x5a, 0x0a,
     0x1f, 0x06, 0x19, 0x1c,
     0x02, 0x07, 0x06, 0x07 };

main() {                    /* Demonstration program */
     int i;
     init_cga();
     strout("Arcom SPCGA character set...");
     for (i=0; i<256; i++) {                    /* Display char set */
          if (!(i%32)) op = (op/LINSIZ+2)*LINSIZ; /* 32 char per line */
          cout(i); cout(' ');                    /* 1 space between char */
     }
```

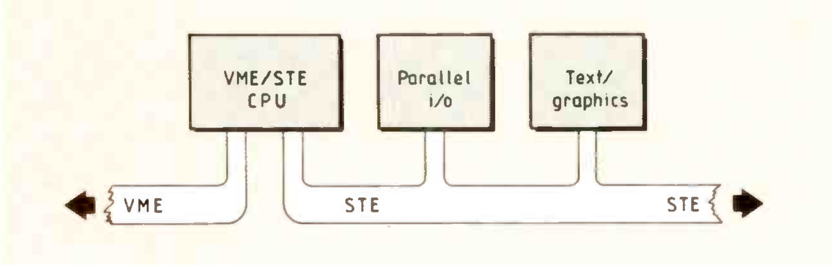
continued on next page

```
}
init_cga() {   /* Initialise CGA, clear screen */
     int i;
     screenb = (char *)(RAMBASE + CGRAM);        /* Set CGA RAM base addr */
     outportb(MCR, 0);                           /* Disable video */
     for (i=0; i<12; i++) {                      /* Set up CRTC registers */
          outportb(IR, i); outportb(DR, data[i]);
     }
     cls();                                      /* Clear screen */
     outportb(CSR,0);                            /* Black border */
     outportb(MCR,9);                            /* 80*25 alpha, video on */
}

cls() {         /* Clear screen */
     long *p; int n;
     p = (long *)screenb;
     for (n=0; n < LINES*LINSIZ/4; n++) *p++ = BLANKL;
     op = 0;
}

cout (c)             /* Raw character O/P to screen */
char c; {
     screenb[op++] = c; screenb[op++] = ATTR;
}
strout (s)           /* Raw string O/P to screen */
char *s; {
     while (*s) cout(*s++0;
}

outportb(addr,byte)  /* Output byte to STE I/O port */
char *addr, byte; {
      *(addr+PORTBASE) = byte; }

importb(addr)        /* Input byte from STE I/O port */
char *addr; {
      return(*addr+PORTBASE); }
```

and automatically translated into four single-byte transfers down STEbus. Since this translation is performed by the CPU hardware, it is considerably quicker than coding four transfers into the software. Word or long-word transfers will always be handled correctly by the VSC020 when accessing STEbus; however, care is needed when using other CPUs or VMEbus. Check on the permissible types of access if a VME board is being driven, and also avoid performing word or long-word accesses starting on an odd address, since earlier CPUs may not perform such accesses in the way you expect.

DEVICE DRIVERS

An OS/9 device driver is a piece of software which has been written so that the device can be fully integrated into the operating system. All devices known to the operating system must have a device driver: as standard, the operating system is supplied with device drivers for discs, consoles etc. Once written and compiled, any extra drivers can be loaded into the operating system, and then all the normal commands can be used with them.



Building computer systems with access to VME and STE, two buses possessing different cost and performance trade-offs, allows major cost savings to be made.

Conventional wisdom has it that for every I/O board in the system, a device driver is needed. However, there is no rule in OS/9 that every I/O board *must* be known to the operating system: what it doesn't know about, it just ignores. Thus, user-mode programs can direct-drive I/O boards, and in many cases this results in smaller, more versatile code, since the programmer is freed from the restrictions and difficulties of OS/9 device driver interfacing.

Device drivers are almost always written in assembly language, because of the detailed interaction with the operating system. It is possible to write the bulk of a device driver in C, with a small assembly language front-end, but only a subset of normal C code can be used. Variables and arrays cannot be pre-initialised, and library functions must be used with great care. For reasonably simple algorithms, such as terminal emulation for the CGA, these restrictions pose no great difficulty, and the Arcom CGA device driver is in fact largely written in C.

It is beyond the scope of this article to describe how to write an OS-9 device driver: it requires a strong will, stout heart, and the OS-9 System Debugger! ■

FEEDBACK

VSWR

I must comment on the article by P.B. Buchan in your December 1988 issue entitled "The VSWR enigma". Whilst not wishing to criticise the author personally. I believe that, rather than explaining the subject from a new angle, he has based his argument on a couple of incorrect assumptions which I hope to clarify.

The first error concerns the assumption that a complex AC circuit problem can be analysed and solved by using facts that relate to a similar, simple DC one. The second is his statement that "power is the rate at which energy is expended".

As far as I can recall from my days of study, this is in contradiction of one of the basic laws of physics, i.e. energy cannot be created or destroyed, it can only be converted from one form to another.

The crux of the author's argument concerns what happens when an electro-magnetic wave from an RF power-generating source encounters a mismatched load or transmission line. Simply stated, if a wave reaches the end of a transmission medium (coaxial cable etc.) and "sees" a load impedance greatly differing from its characteristic impedance, only some of the power/energy will be transformed into another form (radiated) and the remainder will have nowhere elese to go but back down the line to the sending end. Most people accept this fact.

Now the problem is what happens to the remainder of the power when it arrives back at the transmitter (assuming the transmission line has negligible loss). Many people think that mismatch energy is all dissipated as heat in the output stage and leads to excessive device dissipation, possibly resulting in failure of the device. Agreed, some will be transformed into heat and cause some increase in device dissipation. But, as the two impedances are vastly different, the large proportion will act in the same way that the wave did on encountering the mismatched antenna/load: the wave will once again be forced to turn back and will continue to travel from one end to the other until the majority is radiated by the antenna and the balance will be converted into heat in the transmission line and output stage due to losses. Obviously, there will be points of high VSWR at one or more places along the transmission line, which can cause dielectric failure in extreme cases: with well constructed, open-wire lines this is a small danger; with coaxial transmission lines of reasonable attenuation factors, more of the power/energy will be converted into heat and may cause dielectric failure due to excessive temperature and/or voltage breakdown.

In conclusion, the author's argument does not hold water. The output impedance of a transmitter is not 50 ohms, despite what others would have us believe; if that was the case the best efficiency we could expect would be somewhere around 30 to 40% with low-loss components. The author has fallen into the trap of directly using the analogy of the equivalent circuit of a voltage and current source and assumed that it can be applied to RF transmitters. Take a look at the output impedance of an audio amplifier to see the similar problem. Here we drive 4-ohm or less loudspeakers at high current levels, yet we all know that in this case we talk in output impedances of much less than 0.1 ohm!

I believe that the industry is largely to blame, one often sees specification sheets relating to transmitting equipment which fails to distinguish clearly between output impedance and system load impedance.

J.H. Fielding, ZS5JF
Durban
South Africa

Weinstock

I am sure your editorial in the February issue raised more than a few eyebrows in the industry.

Whilst I don't work for, nor am I associated with, any GEC companies, I have worked for the Group in the past.

Your condemnation of Lord Weinstock is less than fair. In the years that he has been chief executive of the GEC Group of companies, he has brought together the biggest *and most profitable* engineering group in the UK. Many smaller companies taken into the GEC group would have disappeared but for GEC.

Your appraisal of 'The Nimrod Affair' is altogether one-sided and viewed with hindsight. When the project first started, no-one had any real understanding of the complexity of such a project. Furthermore, the 'customer' (the MoD) could not specify their requirements. As developments took place through the years so the specifications changed – in the vernacular they kept moving the goal posts. I am not claiming that GEC were entirely blameless, but let us make sure that the blame is shared with those who change their minds.

May I point out that no British or European country has the wherewithal to compete with the semiconductor giants of the USA and Japan. Furthermore, it was never GEC's policy to do so. They manufacture leading-edge, specialist semiconductors and have never intended to get into the feast-famine standard markets.

Finally, may I point out that GEC is the biggest employer of electronic engineers in Britain and furthermore has proved to be a good investment for its shareholders.

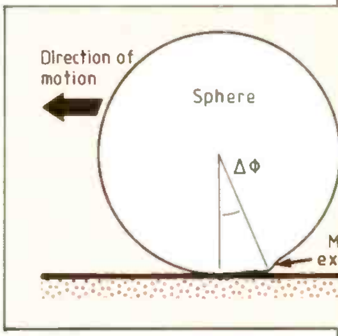
T. Jeffrey Burton
T. Jeffrey Burton Associates
Tunbridge Wells

Ball-bearing motor

Stefan Marinov fails to hit the nail on the head in his description of the principles behind the ball-bearing motor (The Intriguing ball-bearing motor, *EWW*, April 1989). I would suggest that the operation of this 'thermal engine' is based on the non-instantaneous thermal expansion of the metal due to electrical heating (I^2R).

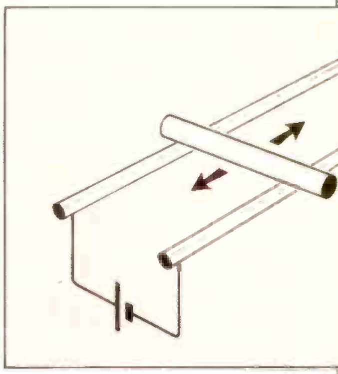
Consider a stationary solid conducting sphere placed on a large flat metallic plate and pressed against it by the force of gravity. At time t_0 a large current is applied between the sphere and the plate, giving rise to local electrical heating at the point of high resistance, i.e. the point contact. As the metal is heated, it will take a finite time Δt for the thermal expansion to reach a maximum, at which point small bulges will have been produced on both the sphere and the plate. The sphere will become 'top heavy' and topple over.

Consider now the second case, in which the sphere has already been set in motion, rolling along the plate. On the application of the current it will again take a finite time for the metal to expand, by which time the sphere will have rolled through a small angle $\Delta\phi$. See **Fig. 1**. It is now



possible to see that the force contributed by the thermal expansion will supplement the momentum of the sphere and, assuming that the friction is extremely small, would ultimately move it randomly across the surface of the plate.

These ideas can easily be extended to the case where two plates are employed on opposite sides of the sphere and moving in opposite directions. It only remains to confine the movement in a single plane and fold it round on itself to create a ball-bearing.

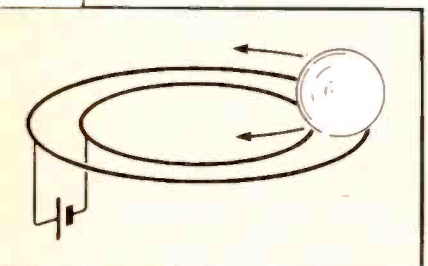


The torque produced by the motor will be proportional to the number of balls; the current flowing (AC or DC); the thermal expansion properties of the metal surfaces; the friction between the surfaces; and the electrical resistance of the point contact.

FEEDBACK

These effects are not confined to ball-bearings alone: linear-type motors may also be contrived. For instance, one idea consists of placing a metallic cylinder on two rails as shown in **Fig. 2**. Once the cylinder is pushed into action it shows a variation on the theme, whereby a metallic sphere propels itself around a circular railway.

The particularly interesting fact, however, is that the two ideas presented here are far from novel: they are culled from 'The Theory of the Nature of Light, Part 5' p.195 by John Harris, published in June 1875. With



reference to the 'circular railway' of **Fig. 3** it is worth quoting the book, as follows:

> *"When the circular base. . . is made level, the ball placed upon the rails, and a voltaic current, copious in quantity and moderate in intensity, introduced at the screws the ball will begin immediately to vibrate, and increase its motions till it revolves on the rails. It revolves with equal facility in either direction. . . and it becomes much heated during its motion."* and further that *"the cause of the motion to be an intermittent thermic action taking place at the surface of contact, at a point a minute distance behind the centre of gravity of the rolling metal."*

Dr Marinov's assertion that the mechanical energy is 'produced from nothing' was obviously an April Fool's joke designed to confuse the majority of readers who probably believe, as I do, that 'you cannot get something for nothing'.
F. Donachie
Watford
Hertfordshire

In the Department of Electrical Engineering of the institute where I was working as a teacher from 1975 to 1985, one of my colleagues liked to intrigue students and teachers with the same ball-bearing motor as the one described by Stefan Marinov in the April issue of *EWW*.

As electrical engineers, we all tried to explain the machine with electromechanics. Some of us considered the ball-bearing motor as a special case of the homopolar machine, which can be considered as a very sophisticated variant of the well-known Barlov wheel. A homopolar machine is a direct-current electromagnetic machine without a commutator and can be used as generator and as motor. It operates with very big currents and very small voltages.

Looking at the rotating ball-bearing motor, we had the idea that the tremendous currents in the connecting wires produced a magnetic field with components perpendicular to the current in the rotor and thus producing Lorentz forces. However, when I stopped the motor with my hand to feel the torque and next tested its self starting capabilities by giving it a flick in the opposite direction, it started to rotate in that opposite direction, opposite to the torque produced by the Lorentz forces!

At that time, this observation killed our homopolar machine model and we left the ball-bearing machine unexplained. There was, however, another observation, that might be crucial for Stefan Marinov's statement that his motor delivers energy from nothing: when it was rotating in one direction the motor ran slower and produced a smaller torque than when it was running in the other direction! I fully appreciate Stefan Marinov's explanation of the ball-bearing motor as a thermal engine, but his claim that it delivers energy from nothing is nonsense.

He remarks: "One can see immediately that the ball-bearing motor has no back tension because there are no magnets, and the magnetic field of the current in the stator cannot induce electric tension in the metal of the rotor." Where currents of ten or even hundreds of amperes are flowing, you can never see immediately that there are no magnetic fields including electric tension in the rotor. (It would have been nice if Mr Marinov had mentioned the metal from which his rotor was made. Ours was steel.)

I am pretty sure that the outcome of the energy measurements will be different for different directions of rotation. If so, we can draw the conclusion that a ball-bearing motor is partly a thermal engine and partly an electromagnetic motor.
Peter van der Wurf
Bosrand
Geldrop
Netherlands

To criticise Stefan Marinov's ball-bearing motor may be to push at an open door, but it would be poor science if I were just to pour scorn on it. Here, then are some explanations of the more glaring flaws in his reasoning.

First, the thermal contraction of the ball bearing is not a direct reversal of the expansion. In expanding, the ball does work by pushing against the inner or outer ring, whereas in contracting it simply loses heat to the air without doing work (apart from against small internal stresses, which in any case operate in the opposite sense from the expansion work, and so increase the discrepancy rather than reduce it). This causes the curve of expansion against temperature to have a hysteresis shape, corresponding to the increase in entropy common to all thermal engines. This in turn means that more electrical energy has to be put in than the mechanical work got out, so in no way can the motor be said to run on zero energy.

Secondly, the calorimeter experiment proves nothing except what we know already, namely that all of the electrical energy becomes heat eventually – even the part which temporarily becomes mechanical work. Now, if Marinov could repeat the experiment with the motor generating heat equal to the electrical energy *and* with the axle protruding from the calorimeter doing useful work in the outside world, *then* we would have something worth looking at.

Finally, the reason for the reduction in resistance at higher currents is trivial. At higher currents, the balls expand more, and so the area of contact between ball and ring is greater.

There may be some uses for a motor based on this design, but energy for nothing it is not!
Tim Bierman
Hendon
London NW4

Faster than light?

The interesting and varied explanations for the Obolensky effect, submitted by your correspondents in *EWW*, March, 1989, show how valuable such letters are. Here was an experiment giving results of apparent superluminal speeds, and now we have a plethora of possible explanations requiring nothing of the kind! Yet the fact that those explanations *were* varied means that there was no unanimous opinion on several points.

(a) Where did the precursor signal originate? (At the relay? On the braided cable? Within the conductor? At the oscilloscope terminals? Previously induced within the oscilloscope? By stray coupling? etc.).

(b) When did that precursor signal begin? (The experiment had no independent timing device to indicate this vitally important instant).

(c) How did that precursor signal travel? (Through the air to the oscilloscope? On the outside of the cable? Through the braiding of one cable to the conductor of another?)

(d) When did that precursor signal reach the oscilloscope? (The experiment has no independent timing device to indicate this second, vitally important instant).

Although your correspondents made the above assumptions given in brackets, any epoch-making experiment should not require that an explicator is forced to make assumptions. No doubt many of your correspondents (or the authors) could suggest ways in which the above points could be obtained with certainty.

Do we have to use cables for discovering precursor signals? Why not send a signal pulse to the Moon?
A.H. Winterflood
Muswell Hill
London, N10

I still think that the Pappas/Obolensky thing is all a leg-pull. How else can we explain an arithmetic where the closer together two signals arrive, the greater the difference in their speeds (*vide* the three 39ft figures in Table 1); ditto where 620,000 km/s is only twice 200,110 km/s; signals which are "proved" not spurious because they conform with the theory that has been constructed to account for them; plates which are added to "enhance the signals" (not to mention the blast of radiation) but then nothing is done to show that it still works with that bit shut up in a good, sound Faraday cage; and information which might have given some of the game away, on the last two photos, conveniently falling off the bottom of the page? Perhaps by being so thoroughly impolite as to suggest that it is no more than extremely poor science?

However, some people seem happy to take it seriously. I think that Messrs Winterflood and Bierman have both overlooked what little evidence we can get out of those last two photos. In the latter's case, however, the results of this need not be quite so fatal to his proposal. If the extra cable (about 6ft?) was inserted right up against the oscilloscope and perhaps coiled up neatly out of the way, he is probably still on the right track. More information is needed.

Nonetheless, until someone with a bit of time (and access to some suitably exotic 'scopery) repeats some of the results, and then shows that they repeat yet again with the "hot" end screened off, I don't think we should bother any more about it.

Alan Watson
Pollença
Mallorca

Crossed-field antenna

I read the article on the crossed-field antenna with a great deal of interest (*EWW*, March, 1989, p.216). However, the field diagram in Fig. 6 troubled me deeply. Joules Watt (*EWW*, July, 1987, p.698) has caused me similar concern. French and Tessman wrote an excellent paper (*Am. J. Phys.* [1963]: 31, 201) in which they calculated the magnetic field at the edge of a capacitor that was being slowly discharged. For the convenience of *EWW* readers, I have repeated this calculation below. The radius of the capacitor plates = R and distance of separation = d.

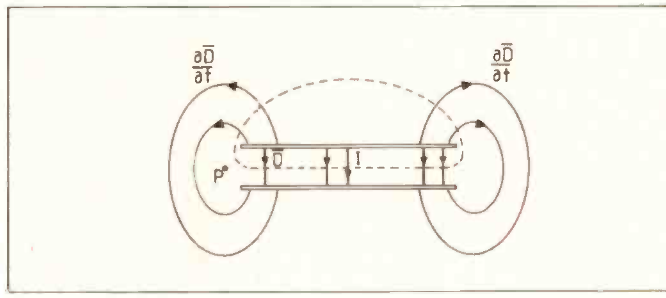
At P $$2\pi RH = \iint \bar{J}.d\bar{s} + \iint \frac{\delta \bar{D}}{\delta t}.d\bar{s}$$

$$2\pi RH = I - I\left\{1 - \frac{d}{2R}\right\}$$

$$H = \frac{Id}{4\pi R^2}$$

M.G. Wellard summed up the dilemma with Maxwell's equations (*EWW*, April, 1983, p.45): "The present confusion in e.m. theory lies in our failure to differentiate between electric displacement and displacement current." The above derivation would make one reach the following conclusion. A capacitor 'works' because of the presence of fringing fields, therefore a displacement current is the existence of a non-uniform field and lines of displacement must be uniform: a uniform electric field cannot change with time. The next question that needs asking is: how do you differentiate between space and time? If you asked a very intelligent child (say the young James Clerk Maxwell) what space was, he might come up with the following statement. I must define space so that there is no temporal implication, therefore space is a condition that is, always was and always will be. It is analogous to the existence of lines of $\bar{D}$ in a capacitor. Lines of $\bar{D}$ are by definition uniform. If a field is uniform, then it is physically impossible for it to become non-uniform. Conversely, if a field is non-uniform, it is physically impossible for it to become uniform. A non-uniform field is analogous to the existence of time. Time can never begin or end; it must always exist in closed loops.

A capacitor is supposed to be a condition of perfect space: i.e. it is, always was and always will be. However, when we try to create perfect space and convert $\partial\bar{D}/\partial t$ into $\bar{D}$, we succeed only by shorting out the capacitor plates. In other words, the concept that we call space – emptiness – is really solid and not hollow! Space is, by



definition, instantaneous (since it is solid). The only observation in nature that is valid is the belief that change is important. Everybody forgets that change is always happening. Now once you mistakenly believe that change can begin and end, you start to invent the meaningless concept that we call space. You also invent the meaningless concept of electric charge. $\bar{D}$ and $\partial\bar{D}/\partial t$ are mutually exclusive. A curved line cannot unlock itself and become a straight line. It is physically impossible for space or electric charge to change with time. Beginnings and ends do not exist in nature.

Finally, has anyone ever wondered why we call the circles, that surround a conductor $\bar{B}$ and not $\partial\bar{B}/\partial t$ in view of the definition of $\partial\bar{D}/\partial t$? I presume that the answer is that we assume that a uniform field exists along the axis of the induction coil and can therefore postulate the existence of imaginary magnetic charges at either end of the coil and thus invent a magnetic capacitor. The same argument applies to an inductor. If we wind a conductor in a helix, then the current should be considered $\partial i/\partial t$ at since the current is now rotating. At least Ivor Catt is consistent in that he knows that energy current exists in closed loops in the active state and they must therefore exist in closed loops in the inactive state.

Lawrence A. Jones
Endress and Hauser
Manchester

I read your article on the Crossed-field Antenna (March 1989) with interest, having been introduced to it by Mr Hateley at a conference in 1987. Antenna engineers, of whom I am one, regard this device with considerable scepticism on both theoretical and practical grounds.

The authors' attempts to ascribe causative properties to Maxwell's well-known equations describing electromagnetic phenomena are misleading and erroneous. The presence of a quantity on the left-hand side of an equation is not, as the authors try to assert, sufficient evidence for its physical existence. In fact, in equation (4), one can let the frequency tend towards zero, in which event the conduction current density J becomes equal and opposite to the rate of change of charge density D. Equation (4) then shows that the "resulting" H-field tends to zero.

In the experiment carried out with capacitor plates, can the authors explain why they have ignored any contribution to the observed magnetic field arising from Maxwell's first equation? The E-field between the two plates must be appreciable and if they wish to use Maxwell's equations in a prescriptive rather than a descriptive manner they must apply the principle consistently.

A further theoretical objection to the analysis given is that the conduction currents in the wires feeding the two sets of plates are ignored. A true analysis of the crossed-field antenna would undoubtedly show that any radiated power arises from these currents. No doubt the antenna will radiate some power but as yet there is no evidence that its radiating efficiency is any more than other antennas of a similar size (i.e. 10% or less).

The value or otherwise of the crossed-field antenna could be very quickly established by an experiment conducted by any generally-accepted method. The radiated field produced at some large distance from the antenna should be measured and related to the RF power being input to the antenna terminals. The IEEE Standard Test Procedure for Antennas (IEEE Std. 149-179)

FEEDBACK

offers one such procedure by which the authors could (maybe) silence their critics immediately. Can they explain why this has not been done? Until it is, the verdict on the crossed-field antenna must remain "not proven".
A.G.P. Boswell
Great Baddow
Essex

Software productivity

I fully agree with the views expressed in Brian Frost's excellent article in the April 1989 issue of *EWW*, as I have come through almost exactly the same programming development phases myself, and reached substantially the same conclusions as Mr Frost.

Having started with mainframe Basic nearly twenty years ago, I progressed through those dinosaurs Fortran 66 and Fortran 77 to several assembly-language variants, including 6502, 6809, 8086 and NS32000. I, too, was very proud of my "hand-coded" and fully optimised assembler routines for real-time image-processing applications. However, just like Mr Frost, I soon realised that something rather better was needed for larger programs and discovered the wonderful TURBO Pascal from Borland. All of Brian Frost's comments on this Pascal variant are sound. The language enables one to develop custom applications-specific functions and procedures. For example, I combine the TURBO Pascal functions "gotoXY()" and "write()" into a very useful "writeat (X,Y, 'string')" procedure for text display.

My biggest disappointment was the C programming language. I expected great things from a system which is said to possess the advantages of low-level assembler and high-level convenience. After persevering with the language over several months at the start of my postgraduate research, I became fed-up after being told that my program contained 38,352 errors when all that was missing was a bracket! I finally gave up C when I discovered that the timings for image processing routines were actually much better in TURBO Pascal. In fact, even my lowly interpreted Basic 4 (running on the Acorn NS32000 Cambridge Co-processor) was almost as fast as the many versions of C (including VAX) that I have used! My own feeling is that the current C craze may wane over the next couple of years, leaving the language back in the hands of the converted.

Mr Frost raises the interesting point about the lack of a great speed increase when moving from 8 bit to 16 bit processors. I have realised this for some years now, and have come to the conclusion that the small instruction set of 8 bit processors, such as the 6502, accounts for the relative efficiency of these older microprocessors. Although 6502 is not a risc processor *per se*, the new reduced instruction set philosophy is at least partially applicable. The provision of complex microprocessor operations, such as multipy and divide, and large instruction sets, all carry a cycle-time penalty. There is therefore the usual trade-off between efficiency and ease of programming in 16 bit and 32 bit processors.

Assembly language has still much to commend it, though. If a macro library is developed, then optimum-coded assembler routines can be almost as easy to use as a high-level language. For example, using macros, one can code

```
@_write ('Opening a data file for
        reading. . .')
@_fopen ('items_file')
@_read (item_1)
. . . . . . . . .
. . . . . . . . .
@_fclose ('items_file')
```

and so on, almost like a high-level language. In fact, large optimised and customised macro libraries, with conditional assembly, can be easier to use than the likes of the C language. Custom macro libraries are the key to fast and efficient coding in assembler.

As Mr Frost observes, programming languages, no matter how functional or exotic, will always attract their own groups of adherents. It is rather like one's personal taste in clothes, music or food.
Thomas McIndoe
Glasgow

Microwave television distribution

After several years of investigation, prevarication, two reports and now a White Paper, the future of broadcasting is still very much confused. The confusion has been intensified by conflicting comments from the DTI "The government should not attempt to determine artificially the success of different technologies", and the Home Office ". . .the government interest was focusing on those frequencies above 30 GHz."

Two points in particular are completely missing from the discussions: power or energy conservation and interference to users of the spectrum, which is a form of pollution. The report from Touche Ross for the DTI concluded that, in the UK, the 2.5 GHz band was already fully loaded and without further investigation ruled this out for the use of microwave distribution of domestic services.

It is a great pity that the current uses of the 2.5 GHz band were not investigated more closely. The main high-power occupancy is troposcatter communications; today, this is not in keeping with good spectrum management or power efficiency. The technique involves directing several kilowatts of RF from a relatively large antenna in the general direction of a similarly large receiving antenna, which collects a few picawatts of RF. The rest of the radiation becomes someone else's interference. As an example of this situation, Jodrell Bank has a research frequency at about 2.67 GHz and, due either to the out-of-band radiation from microwave cookers at 2.45 GHz or interference from some other sources, this line of research has been virtually abandoned. That the troposcatter service has provided good communications in the past is no reason not to look for a more effective alternative. These services could be moved to the spare capacity on the geostationary satellite links using the VSAT concepts (Very Small Aperture Terminals), reducing the size of the ground station antennas, removing the need for servo steering systems and considerably reducing the station costs.

If this could be achieved, then the 2.5 GHz band would become available for the MVDS users in line with Jim Slater's excellent article in the March issue of *Electronics and Wireless World*. Current tests being carried out by the Broadband Systems Group of Manitoba Telephones in Canada show that good to very good television pictures are received at distances beyond 5 kilometres using 1W of RF power into the antenna. Current add-on costs to the user would be in the order of £150 with about £20,000 per four-channel head-end unit to the service provider.

Since costs for small-quantity production runs, such as would be needed for 30 GHz head-end units, are roughly proportional to the square of the frequency increase, this would be of no help to the hard-pressed interactive cable systems that might otherwise be customers for MVDS.

As for the use of a digital channel over an MVDS link, it can easily be shown with a link power budget that 10mW of RF power from a Gunn-diode-based transmitter and a 50cm diameter antenna can provide digital data at the teletext rate with negligible errors.

It has been shown by work in Ireland that the 2.5 GHz band will support 12 PAL-system 8MHz channels and, since, PAL would appear to have a future of at least 15 more years for terrestrial applications, to describe such a concept as obsolete from the start of a service is inaccurate.
Geoff Lewis
Geoff Lewis Enterprises
Canterbury
Kent

Readers' letters for publication are always very welcome, and it is helpful if they can be kept as short as possible to enable us to print a varied selection. Please do not feel inhibited about starting new hares for correspondents to chase – there is no need to confine your letter to matters already mentioned in the journal – *Ed*

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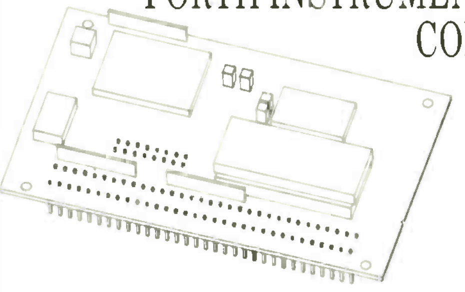

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VISA

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Designing low-noise audio amplifiers

In any system, the front-end amplifier sets important limits to performance. This article examines the limitations of low-noise amplifers as defined by the laws of physics and the practicality of real-world components.

WILFRIED ADAM

Since the invention of electronic amplifiers, their dynamic range (the ratio between the smallest signal just above amplifier noise and the largest possible signal at a given level of distortion) has increased steadily. Despite this improvement, the dynamic range of a modern microphone amplifier is considerably less than the capability of the human ear or of a modern microphone (**Fig.1**). Therefore in the quest for fidelity it is desirable to improve the dynamic range of electronic amplifiers still further.

The main factors behind the expanded dynamic range of modern amplifiers have been an improved knowledge of distortion mechanisms and methods of combating distortion, together with a better understanding of noise sources in amplifiers and the way in which external noises are picked up.

Modern transducers general analogue signals at low level, mainly because of their poor efficiency in converting the input energy into electrical energy. Analogue signal amplification is therefore needed to match the transducer signal to the subsequent analogue or digital signal processing circuitry. The noise performance of this first amplification stage is of considerable importance, because signal information from the transducer which is lost through noise in the first stage cannot normally be recovered through signal processing later on.

One type of interference which influences the performance of the first amplification stage may arise from external sources such as radio frequency signals, in all frequency ranges. Such interference may vary statistically or may be of a repetitive nature. It may be coupled into the amplifier either inductively or capacitively.

Other forms of interference are generated within the amplifying circuitry itself. They are of a statistical nature and are also present at all frequencies. It is on this class of interference that this article will concentrate.

NOISE AND PHYSICS

In audio amplifier design, several varieties of internally generated noise must be considered.

Thermal noise. This occurs at all frequencies and is the dominant noise from around 100Hz right up into the multi-GHz range. The cause of thermal noise is thermal oscillation of electrons; for example, in the crystal lattice of a conductor. Thermal noise is frequently also called Johnson noise or (not quite correctly) white noise – there are other sources of white noise. The amplitude of thermal noise increases with temperature; it is proportional to the bandwidth and the resistance value. The so-called Nyquist equation gives the relationship

$$E_n = \sqrt{4 \times k \times T \times b \times R}$$

Fig.1. Comparison between the dynamic range of the human ear, a modern microphone and a microphone amplifier with a gain of 1000 (60dB).

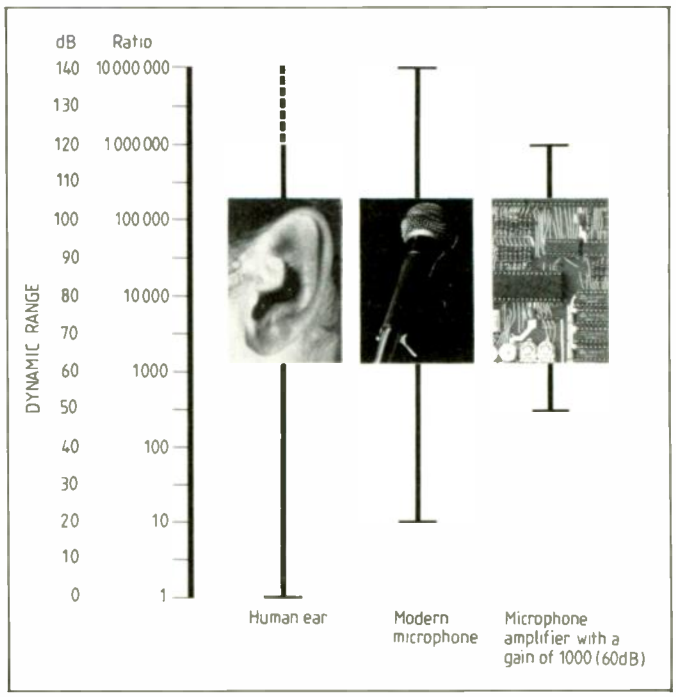
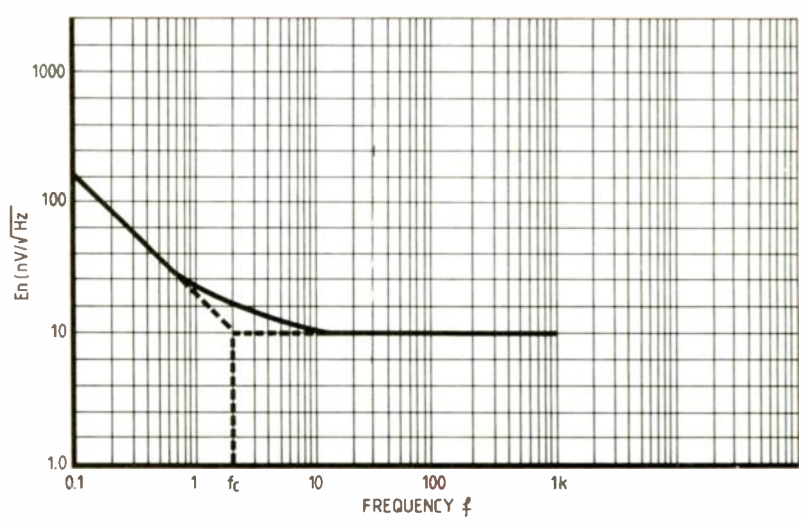


Fig.2. Noise spectral density plot showing white noise and flicker noise components of a bipolar op-amp for audio, and the definition of corner frequency f_c.



where E_n=noise voltage (RMS); k = Boltzmann's constant (1.38×10^{-23}VA s K^{-1}); T= absolute temperature in kelvins; b = bandwidth in Hz; and R = resistance in ohms. Using this equation it is possible to calculate the noise voltage of, for example, a 50Ω (=50V/A) resistor at a temperature of 27°C (300K) and a bandwidth of 20 000Hz (=20 000s^{-1}).

$$E_n = \sqrt{4\times1.38\times10^{-23}\text{VAs}\,\text{K}^{-1}\times 300\text{K}\times 20\,000\text{s}^{-1}\times 50\text{VA}^{-1}}$$

Listec in the table are noise voltages for a number of useful resistances common in audio engineering.

R(Ω)	E_n(nV) b=20kHz	E_n(dBm) b=20kHz	E_n(nV/√Hz)
50	125	−136	0.91
75	153	−134	1.12
200	250	−130	1.82
600	433	−125	3.15
1k	559	−122	4.07

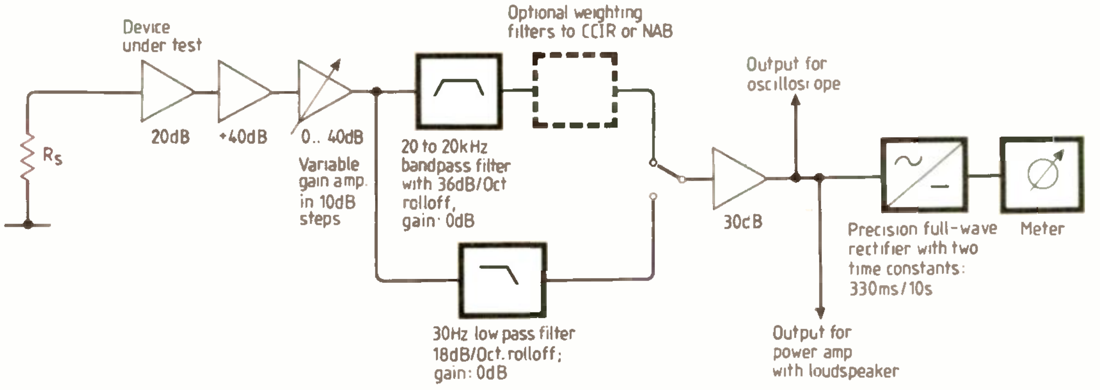
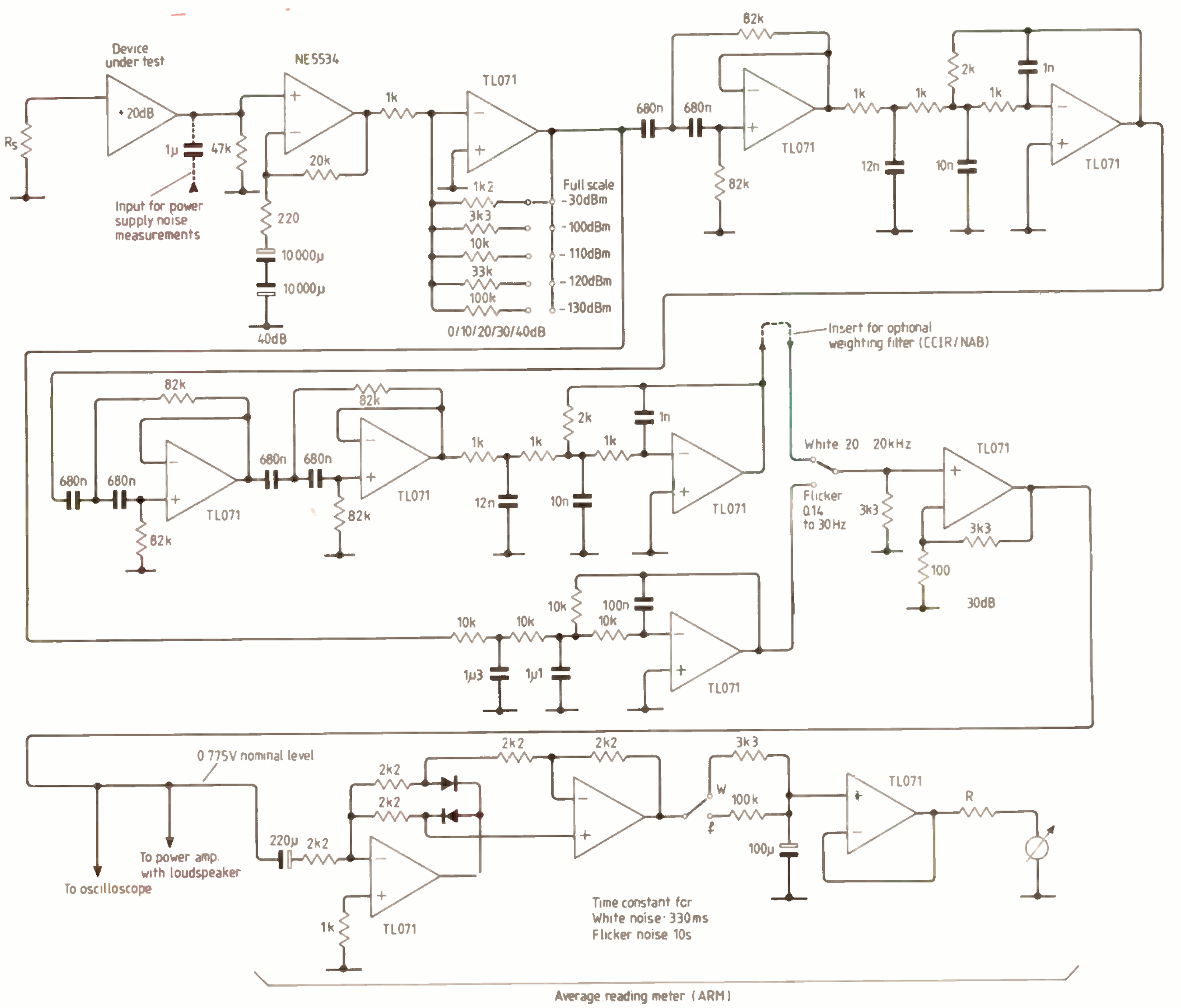
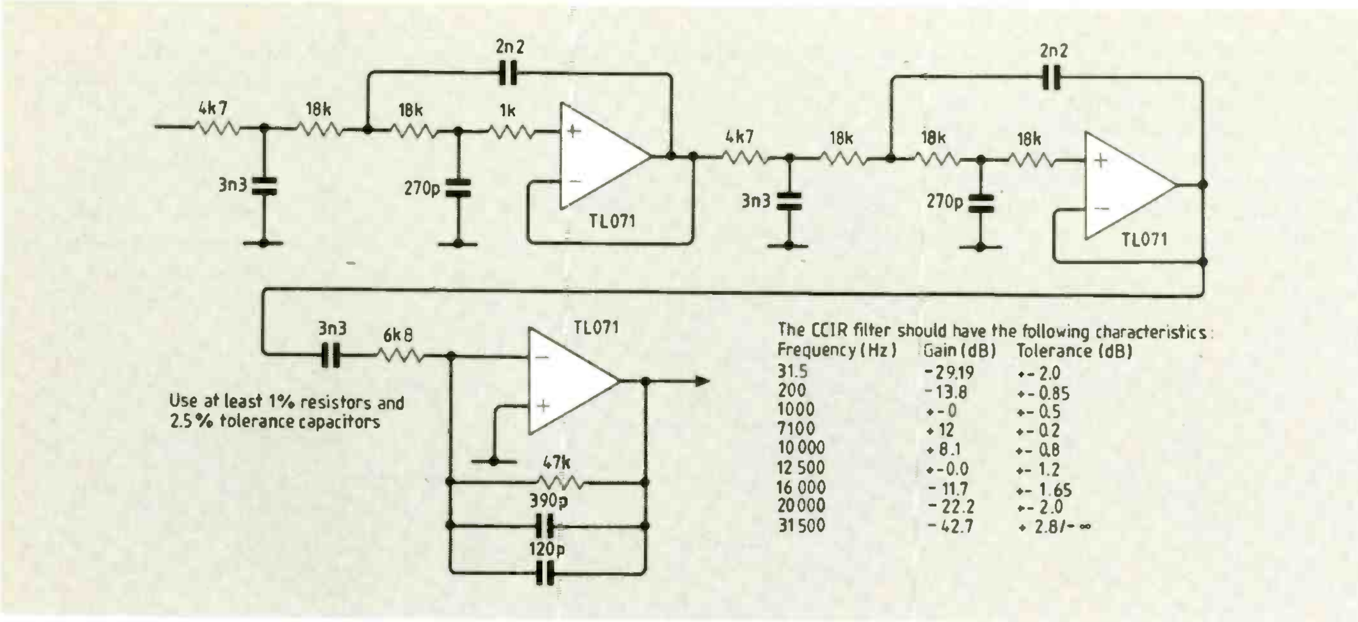


Fig.3. Block diagram of a noise measurement circuit for white noise and flicker noise.

Fig.4. Circuit for the measurement of white noise and flicker noise.



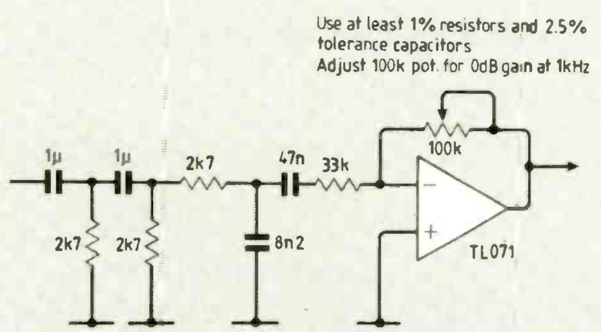


The CCIR filter should have the following characteristics:

Frequency (Hz)	Gain (dB)	Tolerance (dB)
31.5	-29.19	+-2.0
200	-13.8	+-0.85
1000	+-0	+-0.5
7100	+12	+-0.2
10 000	+8.1	+-0.8
12 500	+-0.0	+-1.2
16 000	-11.7	+-1.65
20000	-22.2	+-2.0
31500	-42.7	+2.8/-∞

Fig.5. Optional CCIR weighting filter for the circuit of Fig.6.

In the right-hand column, the table also gives the noise voltage in units of nV/√Hz, i.e. normalized to a bandwidth of 1Hz. This has the advantage that it is not necessary to state the bandwidth to which a particular noise voltage applies. In the case of white noise this is permissible since the noise spectral density is constant – the noise voltage is the same within any bandwidth interval, no matter where this interval is placed in the frequency spectrum.



The NAB filter should have the following characteristics:

Frequency (Hz)	Gain (dB)	Tolerance (dB)
31.5	-39.4	+-3.0
200	-10.9	+-1.0
1000	+-0	+-1.0
2500	+1.3	+-1.0
6300	-0.1	+1.5/-2.0
12500	-4.3	+3.0/-6.0
16 000	-6.6	+3.0/-∞
20000	-9.3	+3.0/-∞

Fig.6. Optional NAB weighting filter for the circuit of Fig.6.

Flicker noise. In taking a closer look at the low-frequency noise from an amplifier in the frequency range below 100Hz one discovers an additional noise component. Flicker noise is caused by material impurities and also depends on the production process employed. The amplitude of flicker noise increases at lower frequencies, where it very much dominates the white noise, especially in view of the small bandwidth under consideration. Since the flicker noise amplitude is proportional to the inverse frequency it is also called 1/f noise:

$$E_{nf}=K/f$$

where E_{nf} is the flicker noise voltage, K a constant of proportionality and f the frequency.

In expressing the amount of flicker noise present in an amplifer, the frequency at which the flicker noise region starts is of particular interest. This corner frequency, f_c is defined in the noise spectral density plot of **Fig.2**. For audio purposes a corner frequency well below 100Hz is desirable.

Besides these two principal types of noise, several others are significant in the design of low-noise audio amplifiers:

Shot noise. Noise from active components such as vacuum tubes and transistors contains, in the frequency range above 100Hz, one further white noise component superimposed on the ever-present thermal noise. The cause of this shot noise lies in the fact that the flow of an electric current depends on the motion of discrete particles – electrons. Shot noise occurs only in active devices. Its voltage is proportional to the current through the device, the bandwidth and resistance:

$$E_s=\sqrt{2q\times I_{dc}\times b\times R}$$

where q equals the charge of an electron, 1.6×10^{-19}As: I_{dc} is the current through the device; b is the bandwidth; and R is the resistance.

Recombination noise. A further noise component only to be found in semiconductors is the so-called recombination noise – noise which occurs when electrons recombine with holes. This type of noise occurs mainly at high frequencies. Its amplitude drops in proportion to $1/f^2$.

Popcorn noise. This noise component occurs at frequencies below 100Hz. It is of an impulsive nature, consisting of momentary changes of the output voltage due to fluctuations in the current through an active device. Contaminated semiconductor surfaces aggravate this type of noise. Other factors which may increase popcorn noise are low temperatures and high-value resistors. The "pops" occur quite randomly with the device, sometimes being absent for several minutes and then appearing several times per second[1]. The precise causes of popcorn noise, or burst noise as it is sometimes called, are not known.

Current flow through resistors. Besides thermal noise, resistors generate excess noise when a current flows through them or when a high voltage is applied. The reason for this excess noise is inhomogeneity in the resistor material. Metal film resistors produce less excess noise than carbon film types and small-sized resistors are noisier than large ones.

Mechanical contacts. Inhomogeneous and unstable contacts in connectors or potentiometers cause voltage fluctuations and are especially troublesome sources of noise.

Vibration. Noise can also be generated by mechanical vibration of components such as vacuum tubes and transistors. This causes a displacement current which makes itself felt as noise. It is especially noticeable in coaxial cables where vibrations cause a change in capacitance. Large components such as capacitors or printed circuit boards are also affected.

Leakage currents. Noise may arise from leakage currents due to contaminants such as finger prints and soldering residues on printed circuit boards or across components.

NOISE MEASUREMENT

To measure noise precisely demands a spectrum analyser, with which to measure the spectral noise density distribution. This instrument is not part of everybody's electronics tool kit because of its price; but simpler means, suitable for the purposes of comparison, may be used for measuring the two principal noise components.

A circuit suitable for evaluating white noise and flicker noise in audio amplifiers is shown in **Fig.3** and **Fig.4**. Its frequency range is 20Hz to 20kHz for white noise and 0.1Hz to 30Hz for flicker noise. Full scale deflection of the meter can be set in the range between −130dBm and −90dBm, so that the lowest noise voltage which can be indicated is in the region of −140dBm (75.5nV). In making measurements it is important to set the gain of the amplifier under test to 20dB, because otherwise the calibration of the range switch does not hold good. The device under test should be well screened from external interference such as mains hum, preferably by a metal box.

Optional weighting filters can be added as given in **Fig.5** and **Fig.6**. Note that the CCIR standard requires peak rectification and the NAB standard true-RMS rectification[2], whereas this circuit provides only full-wave averaging. If gain of the CCIR filter is set to 0dB at 2kHz this will correspond to the CCIR-ARM standard[3].

When switching to the measurement of flicker noise, wait for at least 10 seconds for the meter to stabilize. Usually it will be better to evaluate the amount of flicker noise on a DC-coupled oscilloscope. It is also a good idea to connect a power amplifier with an old loudspeaker to the output, so that one can listen to the noise as long as the loudspeaker can stand it. This helps to identify rapidly any noisy components and amplifiers, or any externally-injected mains hum and radio interference.

Input-referred noise. Results obtained from the instrument are the noise voltages at the input of the device under test; the 20dB gain of the device under test has already been subtracted. The value of input-referred noise is useful because it allows a quick calculation of the noise voltage at the output of the device for any gain setting. For example, the input-referred noise of an amplifier is −122dBm. At a gain of +20dB the output noise level will be −122+20=−102dBm and for a gain of +32dBm the output noise will be −90dBm and so on.

Optimum source resistance. By taking a series of measurements with different resistance values, preferably using fixed-value metal film resistors, connected to the input of the device under test, it is possible to determine the optimum source resistance of the amplifier under test. This is the source resistance at which the difference between the noise generated by the amplifier and the noise of the source resistance is at a minimum. **Figure 7** shows an example for the popular low-noise op-amp NE5534. From this diagram it can be seen that the optimum source resistance is approximately 5kΩ.

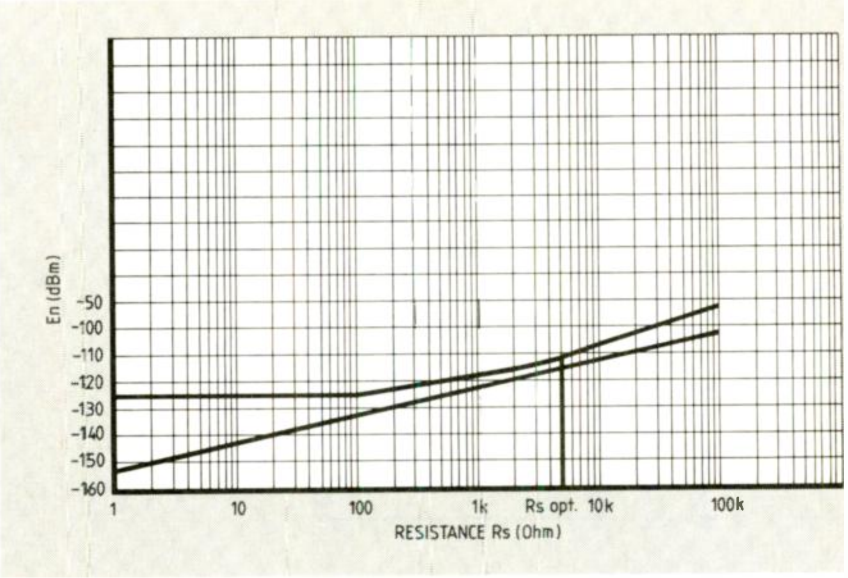


Fig.7. Optimum source resistance of an NE5534 op-amp (typical example without flicker noise in the audio band).

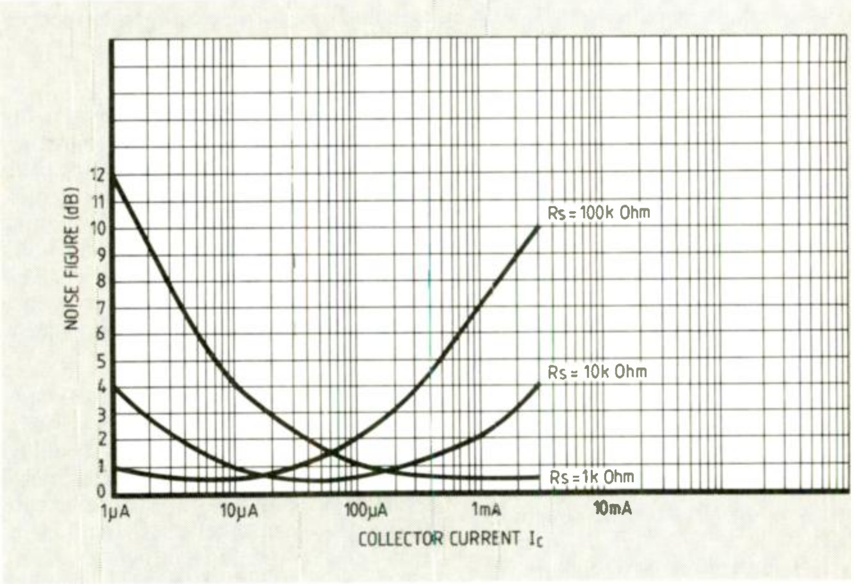


Fig.8. Noise figure and optimum source resistance R_s as a function of collector current I_c for an LM394 transistor.

LOW-NOISE DEVICES

Bipolar transistors. P-n-p transistors are preferred in low-noise transistor circuits because of their marginally better noise characteristics at low source resistances, compared to equivalent n-p-n devices under the same conditions. The magnitude of the collector current influences the value of the base spreading resistance R_{bb} and thus the achievable optimum source resistance of a particular circuit. This is demonstrated in **Fig.8** for the LM394 transistor.

The base spreading resistance is effectively in series between the input terminal and the base of the transistor and generates most of the noise within the transistor. Unfortunately the value of base spreading resistance is not normally stated in manufacturers' data sheets and it cannot be measured easily.

This leaves the designer with three options when selecting a transistor for low-noise circuits:

1. Use special transistors designed for low-

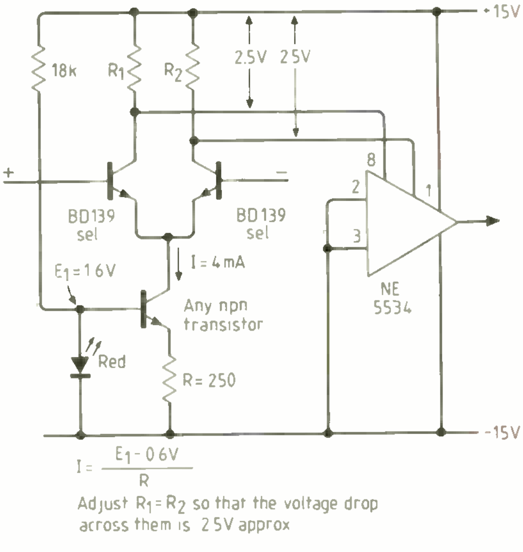
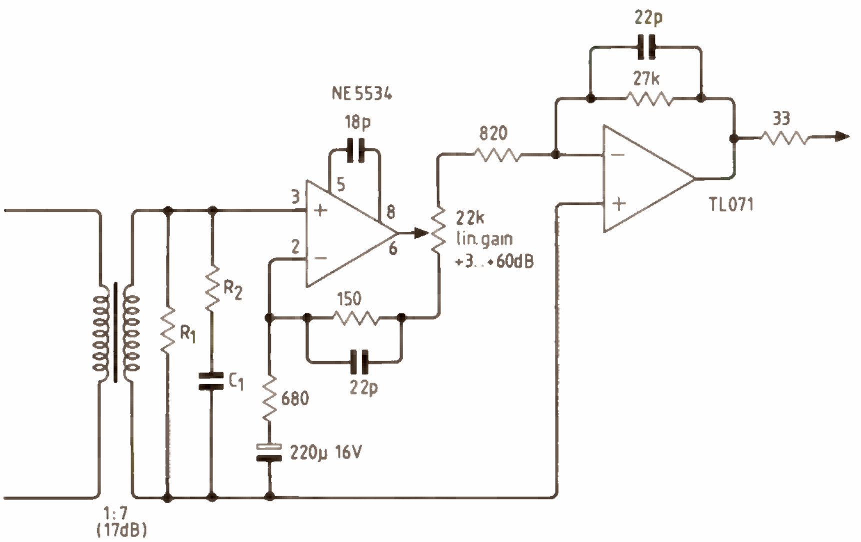


Fig.9. NE5534 op-amp with substituted differential transistor pair for optimum source resistance matching.



Frequency compensation:	R1	R2	C1
for RÜP 498M (Pikatron, F.R.G.)	22k	3k3	270p
for 3195 (Dr. Sowter, GB)	–	22k	150p
for JE-115-K (D. Jensen, USA)	–	–	–

Fig.10. Microphone amplifier with NE5534 op-amp and transformer for optimum source resistance matching.

noise purposes such as the MAT01 (dual)[4], MAT03 (dual)[4], MAT04 (quad)[4], LM394 (dual)[5]. This may be expensive or the devices may be hard to obtain, but the advantage is that one can be sure that these devices are matched and will be essentially free of flicker or popcorn noise, because they have been screened by the manufacturer.

2. Use medium-power RF transistors. By design these transistors exhibit a low value of base spreading resistance, 4-30Ω being common, and they are usually free of flicker and popcorn noise, although it can be worthwhile to check this using the noise measurement circuit outlined above. A good example is the BFW16A with its R_{bb}' of less than 5Ω[6].

3. Use medium-power AF transistors. The familiar BD140 or medium current switching transistors such as the 2N4403[7] will work well because the chip is fairly large, as they are designed to handle currents of around 1A. They therefore exhibit a correspondingly low value of base spreading resistance. They are easily available, but before being used in a low-noise amplifier should be screened individually for low flicker and popcorn noise with the noise measurement circuit.

If the optimum source resistance obtained with one transistor is not low enough, several may be connected in parallel. This method suffers from diminishing returns, because the noise-free gain increases by the factor n, where n is the number of devices in parallel. For example, 50 transistors are paralleled within the LM394. Moreover each transistor may have to be screened for low flicker and popcorn noise. This can become quite unpractical when using a large number of devices per amplifier. Emitter resistors are necessary because transistors exhibit wide tolerances, but this increases noise because any emitter resistors are effectively in series with the input.

Bipolar transistors may be used with optimum source resistances between 3Ω and approximately 10kΩ. If the source resistance is higher it worth considering field-effect transistors. However, bipolar transistors might be preferable even for source resistances where field effect transistors might be used, because bipolar devices have a much lower flicker noise corner frequency of 1Hz to 100Hz; fets exhibit corner frequencies between 100Hz and 1kHz.

Field-effect transistors. If the source resistance is higher than approximately 10kΩ, n-channel field-effect transistors should be used on account of their lower current noise at high input resistances[8]. P-channel fets are noisier than n-channel ones. Here again, special low-noise devices such as J202[9], J203[9], NF5101[10], 2N4867A[10], 2N6483 (dual)[11] may be used although the good old dirty 2N3819 or BF264A will still do the trick, if measured for noise. Modern low-noise fets can be made to work at optimum source impedances as low as 500Ω if you dare (noise corner up to 1kHz).

Mosfets have no place in the front-end of low-noise amplifiers because their optimum source resistance is well above 100MΩ or so[12].

Bipolar, fet and c-mos op-amps. Bipolar op-amps can be selected by the noise voltage quoted in the data sheet and the curve giving the optimum source resistance. The flicker noise corner frequency of bipolar op-amps ranges between 1Hz and 100Hz compared to 100 to 1kHz for fet op-amps. C-mos op-amps also have corner frequencies in the region of 1kHz. With cheaper types of bipolar beware of flicker and popcorn noise. Frequently op-amps are stated to have low noise; this may have been so at the time they were first marketed, or they may be the lowest-noise devices of a quite noisy family.

Low-noise op-amps by today's standards are the LT1028[13], LT1037[14], OP4,[4], OP37[4], ZN459[15], ZN460[15], SSM2016[16] and SSM2134[16]. The NE5534 or the improved LM833 are standard devices for use in many low-noise circuits, although they have to be monitored for noise performance.

Op-amps may be paralleled by summing their outputs, to reduce the value of the optimum source resistance. But this technique suffers from the limitations described above for the paralleling of transistors.

Hybrid devices. There are some very good hybrid or discrete op-amps, such as the Transamp LZ[17], the Matchamp XTX129[18] or the Jensen JE990. The latter is notable for excellent op-amp design[19]. Besides being very low-noise devices with optimum source resistances in the region 200-500Ω, these components have the additional advantage of extended ±24V supply rails, thus increasing dynamic range by a further 6dB or so.

LOW-NOISE CIRCUITS

In designing a low-noise amplifier, the foremost task is to adapt the optimum source resistance of the amplifier (that source resistance at which the amplifier is quietest) to the value of the AC source resistance provided by the transducer. It is usually a good idea to measure the resistance of the source, as manufacturers' data usually states only the DC resistance, which in our case does not help, or some sort of nominal value. Source resistance is best measured by connecting a resistor across the source terminals and determining the resistance value at which the output drops by half. This is preferably done at several frequencies – say 100Hz, 1kHz and 10kHz – within the audio band. The average of these values is taken as the source resistance to which the optimum source resistance of the amplifier is to be matched. The maximum value of the three should be multiplied by 10, giving the input resistance value for which the amplifier has to be designed.

There are three different ways to lower the optimum source resistance of a given amplifier.

- Collector current through the transistor. Let us consider a common dynamic microphone having an average source resistance of 100Ω and a common low noise op-amp with an optimum source resistance of 5kΩ **(Fig.7)**. As **Fig.8** shows, the collector current determines the optimum source resistance of a transistor stage. For the given source resistance the corresponding collector current is around 2mA per transistor. If such a diagram is not at hand, for example when using medium-power transistors whose noise performance is not specified by the manufacturer, the following rule[20] may be applied:

$$I_c = \frac{\sqrt{\beta}}{40 \times R_s}$$

where I_c is the collector current, β is the current gain of the transistor and R_s is the source resistance. The collector current must be within the limits given in the data sheet of the transistor.

One can, of course, place a differential stage running at 2mA per transistor in front of the NE5534, but this creates stability problems. These can be avoided nicely by substituting the input differential pair of the NE5534. This is done by taking the normally used inverting and non-inverting inputs to −15V and feeding the signal from the difference amplifier running at 2mA per transistor into the offset adjustment pins 1 and 8. These are internally connected to the collectors of the now disabled internal differential pair (**Fig.9**). It is also necessary to parallel the internal collector resistors with external resistors so that the collector is maintained at 2.5V.

Resistance values around the op-amp should be made as low as possible to prevent the introduction of additional thermal noise from the feedback resistors. The NE5344 supports this, being capable of driving a 600Ω load without reduced output voltage.

- Paralleling. When going for even lower source resistances, several transistors can be directly paralleled as outlined above. However, to avoid excessive offsets at the output, the transistors should be selected so that each one carries the same current.
- Resistance transformation through a transformer. A transformer converts a low impedance into a high impedance and vice versa. If a low signal source resistance is to be matched to the higher optimum source resistance of an amplifier the required transformer turns ratio is given by

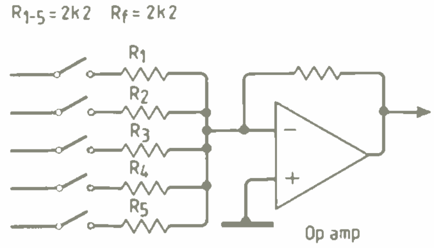
$$n=\sqrt{\frac{R_{opt}}{R_s}}$$

where n is the turns ratio of the transformer, R_s the source resistance and R_{opt} the optimum source resistance of the amplifier. With R_s at 100Ω and R_{opt} at 5kΩ, n=7.

Fig.10 shows the use of a 1:7 step-up transformer with a rather clever circuit[21,22] which allows the gain to be varied over a very wide range of 60dB by a single linear potentiometer, whilst maintaining optimum noise conditions (i.e. first-stage gain is always higher than the gain of the second stage).

Don't be put off by rumours that transformers have a bad reputation. In the days of valves with their high optimum source resistances (30kΩ or more), there was no other way than to use step up transformers with ratios up to 1:20 with consequently nasty frequency response and distortion characteristics, and with less-than-perfect production techniques and materials. However, modern audio transformers are produced using much improved materials and techniques, and excessive step-up ratios are no longer necessary, thanks to the lower optimum source resistance of modern transistors and op-amps.

Inverting summing amplifiers have their particular noise problems, which are due firstly to the unavoidable series input resistor and secondly to the amount of noise gain as defined in **Fig.11**, which shows the circuit of a typical summing amplifier with five inputs. As far as each input is concerned, the gain of this stage is 0dB. But as far as noise gain is concerned there is 14dB of noise gain (2.2kΩ divided by the 440Ω of the five parallel input resistors). This consequently increases the noise level of, say, −110dB to −96dB. So, surprisingly, this stage must be designed for low noise by using, for example, the circuit of Fig.9 as the operational amplifier. What is even worse, the more inputs, the noiser the summing amplifier will be.



Gain for each input: Rf / R = 1 (0dB)

Noise gain:

$$\frac{R_f}{\dfrac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}}} = \frac{2K2}{440\ \text{Ohm}} = 5\,(14\text{dB})$$

Fig.11. Noise performance of the inverting summing amplifier with five inputs.

TRAPS AND PITFALLS

Besides taking into account the design rules outlined above, you should note some pitfalls to avoid.

Reverse biasing of transistors. During tests with an ohmmeter or while the circuit is being switched off, the transistors may become reverse biased, leading to an increase in flicker and popcorn noise. If, for example, a circuit measures well the first time after it has been switched on and develops noise the next time it is used, it is very likely that the transistors are briefly reverse-biased during switch-off This fault can be cured only by changing the discharging time constant in question and replacing the front-end transistor.

Power supply noise. Noise can be injected into an otherwise low-noise power amplifier via the power supply. Circuits usually exhibit good power supply noise rejection ratios of typically 120dB at 50 or 100Hz, but values decrease significantly to 20–40dB in the range between 1 and 20kHz. This means, for example, if there is a noise level of −60dBm on the power supply voltages (a value typical for most fixed-value voltage regulators), a noise voltage of −100dBm will appear at the output of the low-noise amplifier, if its power supply rejection ratio is 40dB. So some care must also put into the design of low-noise power supplies. Consequently all types of switching power supply should be avoided in such applications because they cannot be made to run sufficiently quiet. Zener diodes also produce significant amounts of white noise if not properly bypassed with low series-resistance capacitors.

Noise levels of power supply voltages can be measured by connecting the supply voltage via a capacitor to the input of the NE5534 amplifier (Fig.4). Note that in this case 20dB must be subtracted from the calibration values of the stepped gain switch.

Capacitive reactance. When using the input capacitor and input resistor time constant to cut off low-frequency signal components, low-frequency noise is introduced. For example, with a 1μF capacitor and a 10kΩ resistor giving a cut-off frequency of 16Hz, a horribly high series resistance X_r of 8kΩ at 20Hz and still 160Ω at 1kHz is placed in series with the input. This produces considerable amounts of noise. Since the capacitive resistance increases at lower frequencies irrespective of whether you are using foil capacitors or electrolytics, the noise spectrum due to the capacitive reactance is similar to that of flicker noise. Designers have spent many hours, happy and otherwise, finding this one. The only thing to do is to use very large and therefore electrolytic capacitors so as to achieve a cut-off frequency of well below 0.01Hz. Bypass the electrolytics with ceramic capacitors, if you must. Remove any low-frequency signal components after the low-noise amplifier stage.

Spurious oscillations. Be warned that intermodulation products of RF oscillations produced by an unstable amplifier will cause unexpected noise. ■

References

1. Harris, Analog Pocket Application Guide No.5: Operational amplifiers (Audio) 1988, p.76.
2. Rohde and Schwarz, Operating Instructions for UPGR.
3. Ray Dolby, D. Robinson and K. Gundry, CCIR/ARM: A practical noise-measurement method, *Journal of the Audio Engineering Society* Vol.27, No 3, March 1979, p.149-157.
4. PMI, Linear and Conversion Products 1986/87 Data Book.
5. National Semiconductor, LM394 Data Sheet.
6. E H. Nordholt and R.M. van Vierzen, Ultra-low-noise preamplifier for moving coil phono cartridges. *Journal of the Audio Engineering Society* Vol.28, No 4, April 1980, p.219-223.
7. D. Self, Design of moving-coil head amplifiers, *Electronics & Wireless World* December 1987, p.1206-1209.
8. John Maxwell, The low-noise JFET – the noise problem solver, National Semiconductor, Application note AN 151.
9. Intersil, Data book.
10. National Semiconductor, Fet databook.
11. Steven W. Smith, Internal noise of low-frequency preamplifiers, *Review of Scientific Instruments* 55, May 1984, p.812/813.
12. M. Hartley Jones, A practical introduction to electronic circuits, Cambridge University Press, p.40-51.
13. Linear Technology, Linear Databook 1986.
14. Linear Technology, Linear Databook Supplement 1988.
15. Ferranti, Technical Handbook Standard ICs.
16. PMI/SSM, Products Data Book
17. Transamp LZ Data Sheet.
18. Hugh Ford, Matchamp XTX 129 mic. preamp., *Broadcast Sound* January/February 1984, p.52-55.
19. Deane Jensen, JE990 Discrete operational amplifier, *Journal of the Audio Engineering Society* Vol. 28 No 1/2, January/February 1980, p.26-34.
20. A. Foord, Introduction to low-noise amplifier design, *Wireless World* April 1981, p.71-73.
21. Steve Dove, Designing a professional mixing console, Part 4: The Mixer Frontend, *Studio Sound* December 1980, p.40-48.
22. Steve Dove, Designing a professional mixing console, Part 12: The Channel Frontend, *Studio Sound* October 1981, p.70-72.

RADIO BROADCAST

Digital audio broadcast systems

Despite steady progress in the introduction of digital audio techniques into the programme chains of radio, television and recording studios, there remain problems in standards; in equipment interfacing, routeing, synchronization, sample rate conversion, and in monitoring. Yet, for example, there now seems little doubt that the future of audio editing will increasingly centre on the use of computer-based, magnetic disc digital systems – possibly with a central store and multiple self-operated desk-top controllers, though the general use of multiple systems may be some way off.

Such matters formed the basis of an IEE discussion at which Richard Lawrence (BBC), Robin Caine (Protel), Tony Griffiths (Decca International) and David Meares (BBC Research) were the panel speakers under the chairmanship of Chris Daubney (Channel 4 Television).

Richard Lawrence noted that although the BBC has been using PCM for signal distribution for 15 years, it is only within the past year that a complete digital audio broadcast chain has been engineered. This was built and installed in Broadcasting House, London, and first used in September 1988. Sources can be from digital audio tape (DAT) or from the digital control vehicle (DVC) using a 1.5GHz radio link, 32-to-48 digital bypass mixer, digital limiter, 48-to-32 sampling rate converter (SRC) and then Nicam companding for distribution to the VHF/FM transmitters where the signals are finally converted to analogue form. Despite this progress, it is recognized that broadcasters will be working in a mixed digital/analogue environment for many years to come.

The AES/EBU 48kHz standard is not error-corrected and needs a fairly clean environment. Precautions are necessary for long cable runs, particularly with mixed cables. Mixing consumer and professional digital equipment can result in balance, level and impedance differences, but it is amplitude levels rather than reflections which tend to cause the most problems. The BBC is currently designing an LSI chip to implement AES interfaces.

Rate conversion between 44.1 and 48kHz samples is slightly more difficult than 32 to 48kHz. Since cascading SRCs can degrade the signal, specifications need to take account of the number that may be connected in tandem.

Robin Caine described a new digital switcher system developed in association with Thames Television. Tony Griffiths commented that Decca was in its eleventh year of digital recording and tended to assume that the "whole world has gone digital". Nevertheless the company is still thinking about A/D and D/A conversion, how to connect it all together, how to make signal processing work. He felt that there is need for more than 16-bit words at the professional front end: "It needs 20 bits to do the job properly but nobody is shouting loud enough. It is not certain that manufacturers are listening."

Digital audio revolution

The London presentations of the IEE's high-profile Faraday and Silvanus P. Thompson lectures, by a BBC team and John Borwick respectively, both placed emphasis on the improvements in audio reproduction in the home, primarily as a result of the digital audio revolution. The Faraday was good entertainment and seemed to win over its young audiences who are encouraged to think of broadcasting as a career. John Borwick may have expected a rather less youthful audience but seemed surprised to find so many white hairs among his house-full audience at Savoy Place. Presumably he had this generation in mind when he suggested that "Resistance to change is enormous – we prefer to stay with what we have". A view not entirely borne out by the boom in CD equipment and discs.

He listed 14 advantages of digital audio compared with six disadvantages. Advantages include predictibility, robustness (with error correction), copies exactly duplicated, quality unaffected by the type or quality of the transmission or storage medium, wide dynamic range, no significant distortion except on low-level signals, no wow or flutter, low crosstalk, exact channel synchronization, no print-through, and accurate editing and processing.

The disadvantages he listed were cost, revolutionary rather than evolutionary change, the need for basic standards which are still lacking, performance "fixed in aspic" for all time by the sampling frequency and number of bits, high power consumption, and noise and distortion at low signal levels – as present for much of the time in classical music.

He compared analogue audio to a glass of water: fluid, fragile, exact. Digital was a glass filled with marbles: discrete, robust and approximately. Digital audio permits the restoration of "non-ideal" recordings, and not only old recordings. Such techniques, he suggested, are proving "modestly successful".

John Borwick stressed the current use of digital audio in professional recording studios for some broadcast origination, but concentrated mainly on the evolution and progress of CD records. He had surprisingly little to say on broadcast digital transmission in spite of the imminent introduction of Nicam 728 for terrestrial television stereo sound and digital packet multichannel sound on D-MAC satellites. He remains unconvinced that consumer DAT will prove a viable consumer product: "price wrong, market wrong – not selling in Japan – it may never happen." CD, on the other hand, is spawning CD-V, CD-ROM, CD-I (interactive), CD-R (recordable) and CD-E (erasable) though this may be some years away. There is also the prospect of the still unrevealed CD-X. He feels that 16-bit words are adequate for consumer play-out but additional front-end digits permit improved processing during manufacture.

Illegal RDS?

Following the publication in the March *E&WW* (page 316) of my item on the pros and cons of RDS, I received a letter from S.H.F. Sarl (Stanley Sarl & Associates) questioning the legality of RDS and other data broadcasting systems. He believes that such systems, even when used as ancillary services to broadcasting, are in breach of the licences issued to broadcasters under the present Wireless Telegraphy Acts. His controversial views are set out in detail in "Regulating a radio data system" in the December 1988 issue of the *Journal of The Society of Engineers* (SoE Journal).

As someone who was obliquely concerned at the IBA with questions involving the introduction of teletext, radio-text (SCA) etc., it always seemed to me that data broadcasting as an ancillary service, provided it was conducted with full Home Office/DTI permission (as was obtained) could not be challenged on legal grounds.

A much greyer area was where the data is directed at private "subscription" users on an individually addressed basis – to my mind a telecommunications rather than a broadcasting service. It was this consideration that delayed the introduction in the UK of such services on VHF radio for a number of years. It was resolved on the rather dubious principle that it became broadcasting if decoders had to be made available (at a price) to anyone who demanded one.

I still wonder how the transmission of electricity control signals on 198kHz can be classified as "broadcasting"; and the same goes where RDS is used for radio-paging as it is in some countries (not the UK). But then we seem to be tolerating other legal quibbles such as the DTI's permitting direct reception of fixed-service satellites (such as Astra) in the home. It is highly questionable whether transmissions outside the internationally agreed "broadcast" frequencies can be considered as "duly authorised broadcasting stations". ITU Radio Regulations are supposed to have the status of an international treaty – but it is not unknown for treaties to be broken when it suits governments to do so! I doubt if Mr Sarl will succeed in having RDS declared illegal, even though he has a valid point.

Pat Hawker

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TSKO	Enables up to 4 x TCFL4 or TCFL2 to be combined.

Prices

CCIR/5-1	1 Modulator	£109.76
CCIR/5-2	2 Modulators	£167.99
CCIR/5-3	3 Modulators	£237.59
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