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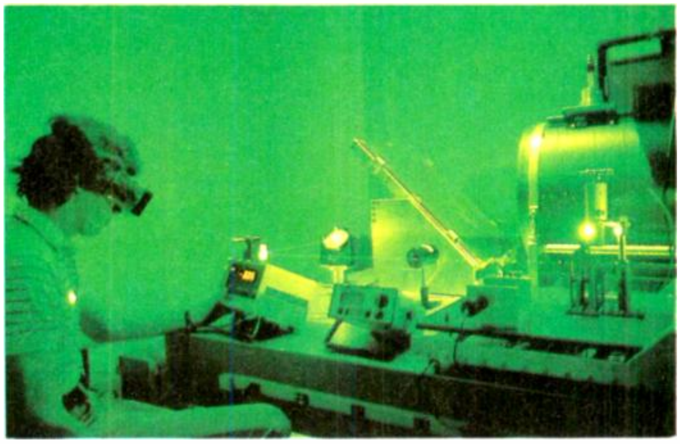

A frequency doubled YAG laser probes the upper reaches of the atmosphere with the optical equivalent of radar. These new instruments are revealing secrets about high altitude haze layers, significant contributors to the greenhouse effect. Page 1057.

REGULARS

In next month's issue. Vogager's astonishing pictures of Neptune and its slushy moon Triton mesmerised scientists the world over. The mission has been a triumph of technology. Research Notes writer John Wilson gives his own account of how it was done. We also look inside modern communications satellites.

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High tech junkies

"The Japanese semiconductor manufacturers are behaving like a bunch of crack dealers". Not our words but those of outspoken AMD boss, Jerry Sanders, chairman of a billion dollar US chip company.

He made the analogy in discussing the West's increasing dependence on Japanese commodity semiconductor parts such as d-rams and eproms. He reckons that the Japanese ambition is to hook the West's dominant computer companies by feeding them cheap memory parts, destroy the indigenous chip industries through selective dumping, jack the price on chips from the remaining Japanese sources and thus render US and European equipment producers uncompetitive. The end objective is to kill the West's equipment industry through financial warfare.

Naturally the United States won't allow this to happen. It has already acted in the defence of its commercial equipment makers and the associated semiconductor infrastructure by creating joint ventures such as US Memories and Sematech. The US has always safeguarded the military infrastructure through the long established VHSIC programme. It has yet to use its final defensive weapon, trade regulations along the lines of those employed in the auto industry, but it won't hesitate if the day should come.

The dynamic US reaction to a very real Japanese threat is in complete contrast to the European response.

Essentially, there isn't one.

Good Europeans stumble around muttering "1992 will take care of all that". This is actually code for "Let's waive the anti-trust laws and allow the euro-multinationals to coalesce however they wish. Bigger is more secure even though the euro-consumer has less choice."

And that's what has happened to our very own Plessey company, a victim of a cosy telecomms and defence duopoly, Siemens and GEC.

One may argue that Siemens has some claim to commodity semiconductor manufacture. It makes rams but, on the world scale, it might as well not bother. GEC didn't. The British company has never looked beyond supporting its lucrative defence and telecomms interests. The threats from Japan never entered the calculations.

Here lies the great danger. The US will fight a vigorous battle against the Japanese. The Rising Sun knows this and will elect to tackle the Americans as part of a second front. Japan will content itself initially with subjugation of European equipment makers. The removal of the vibrant Plessey Semiconductor operation into the dead hands of Siemens and GEC will make the process a little easier.

The UK's national position is even worse. Inmos has been allowed to pass into Italian ownership and Plessey is being fitted for a straight-jacket. We no longer have an independent semiconductor industry.

Should Sander's worst predictions come true, the UK's equipment industry will have to turn to the Koreans for salvation. Even if the man has spoken a load of rubbish, the reduction in status of the UK's semiconductor manufacture to a screwdriver operation will do little to foster a technology based electronics industry in this country.

Frank Ogden

Hydrogen: the hottest superconductor?

My comments in previous issues about the increasingly unpractical nature of some of the new high temperature superconductors seems to have been borne out by some intriguing research at the Carnegie Institution Geophysical Laboratory in Washington DC and at the University of California at Berkeley. This time the material under investigation was not some esoteric rare earth/copper oxide complex but the simplest material of all – hydrogen. Normally of course hydrogen, with each atom consisting of only a single proton and single electron, exists as a non-conducting gas. When cooled to around −253°C it turns into a clear liquid, excellent for propelling space shuttles but, like its gaseous counterpart, also a good electrical insulator. Even solid hydrogen, formed when the liquid variety is further cooled to −259°C, is non-conducting, though physicists have long speculated that it might become conductive under extreme pressure.

The basis for this prediction is the fact that all other elements with a single electron in the valence orbital are in fact metals and all conduct electricity. So could it be that under certain conditions hydrogen too would exhibit metallic properties? Unfortunately, no-one has been able to squeeze it hard enough. Forget your garage air-line: calculations suggest that hydrogen needs about two million atmospheres before there's the remotest possibility of its turning into a metal.

That sort of pressure – roughly the same as that found in the centre of the Earth – has now become possible thanks to a device called a diamond anvil cell in which the solid hydrogen can be squeezed in a tiny cavity between the faces of two carefully-machined diamonds. Because the diamonds are only 0.5mm across and their cavities even smaller, it's now possible to create the sort of pressures at which hydrogen would become metallic. Better still, because of the transparency of diamond it should be possible actually to see such a change.

In a paper in *Science* (Vol. 244, page 1462), H.K. Mao and R.J. Henly describe an experiment in which they found tentative evidence of transformation to the metallic state. At between two and three million atmospheres pressure the clear ice-like solid hydrogen gradually became more opaque until it looked increasingly like a metal. This colour change is significant because the opacity of familiar metals is due to an electronic configuration that is also responsible for conduction. As to whether the hydrogen in this experiment actually did become electrically conducting wasn't verified, and until someone devises some Avo probes that will penetrate diamond and survive a few million atmospheres pressure, it won't be easy.

Theorists at Berkeley have, nevertheless, gone yet another step further and predicted that if the pressure is increased to about four million atmospheres, then hydrogen will become not just conducting but superconducting. In their latest paper (*Nature* Vol. 340 No 6232) T.W. Barbee III, A. Garcia and M.L. Cohen calculate the atomic structure which they expect hydrogen to adopt at four million atmospheres. They go on to compute that such a structure would superconduct with a transition temperature of −40°C, easily the highest of any known substance.

Verifying this prediction won't of course be any easier than verifying the metallic properties of hydrogen. Nevertheless the models employed by Barbee *et al* have already successfully predicted the behaviour of silicon under extremely high pressures, so it's more than just sophisticated guesswork.

As to the practical value of superconducting hydrogen, my initial remarks are undoubtedly fair comment. Nevertheless, hydrogen is a much simpler material than other high temperature superconductors and one that should appeal strongly to theoreticians anxious to unravel the complexities of why materials superconduct at all.

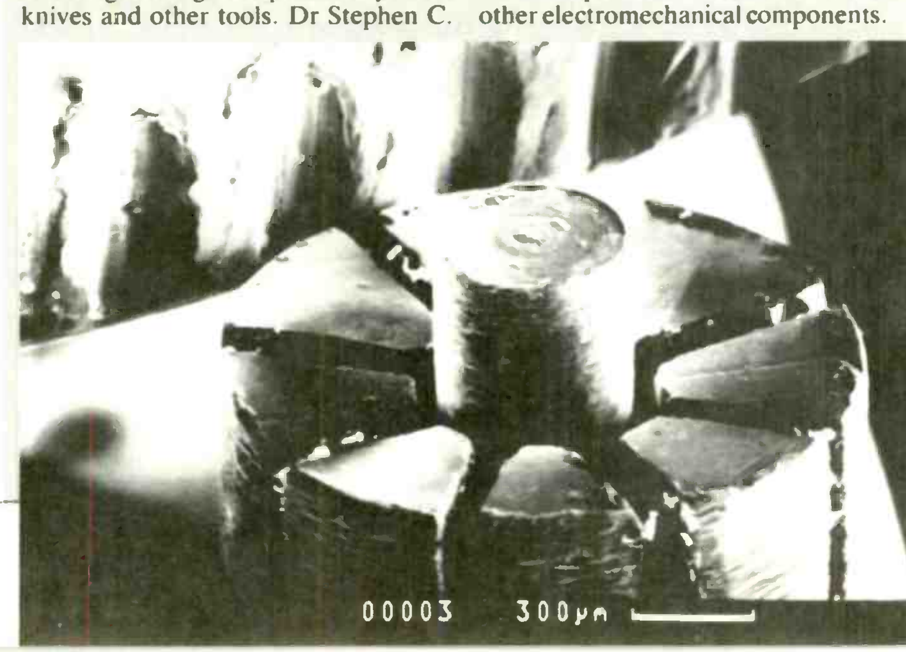
Long-life micro-motors

Tiny electric motors, developed at the University of Utah's Centre for Engineering Design, could one day be used for grinding cholesterol off the insides of furred-up arteries. The devices, called wobble motors, have a diameter of less than half a millimetre and consist of a hair-like rod inside a casing. The name derives from the fact that the armature wobbles slightly as it rolls around inside the casing; this is said to remove the need for lubrication. The units operate up to 120 000 RPM.

The wobble motor, pictured here by a 10 cent coin, avoids the need for complex components by using electrostatic forces instead of conventional electromagnetic principles. Torque is reported to be high enough to operate tiny saws, knives and other tools. Dr Stephen C. Jacobsen, director of the Centre, says that they've already made a successful micro-drill with a 0.05mm diameter bit.

Micro-motors are not new in concept; several US and Japanese researchers have in fact already made them smaller still. What's special about the Utah devices is that they're claimed to be the first units to operate for sustained periods without wearing out.

As well as the possibility of unblocking diseased arteries, Jacobsen foresees his motors being used in scientific instruments, robots, artificial limbs and virtually anywhere where electricity needs transducing into motion. In addition to motors, he's also working on microscopic actuators, sensors and other electromechanical components.



Radar atmosphere probe

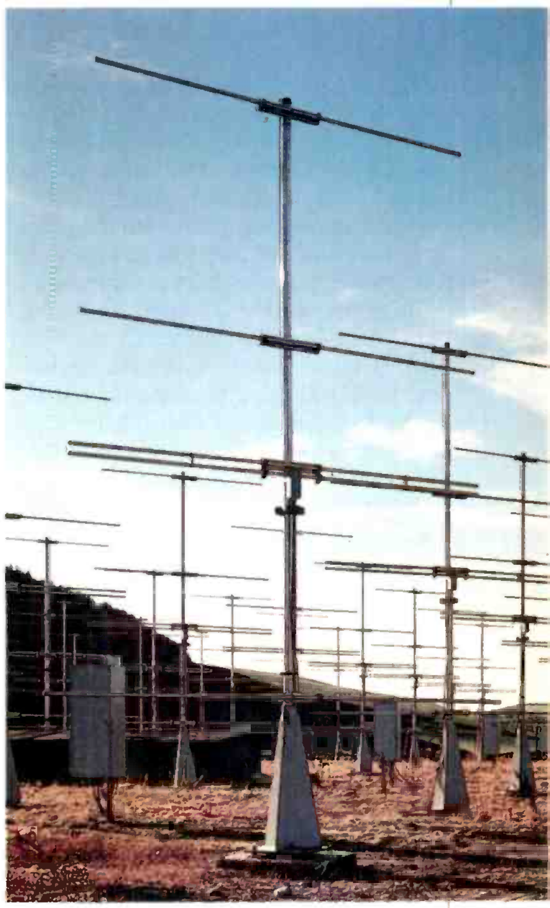
At Capel Dewi, five miles from Aberystwyth, is an impressive antenna farm consisting of 64 vertically-orientated Yagis. It's not, as you might imagine, a system for communicating with extra-terrestrial intelligence, but the first phase of a new SERC facility known as the Mesospheric, Stratospheric and Tropospheric Radar (MST).

When the complete system comes into operation later this year there will be a further 336 four-element Yagis, all linked by a complex network of power dividers and variable phasing arrangements designed to swing the beam up to 12° from the vertical.

At present, the existing 64-element array, powered by two of the planned five 25kW transmitters, can probe the atmosphere up to about 16km. Returning echoes are received on a special high-performance computer-controlled receiver which estimates upper atmosphere wind velocities from Doppler shifts. When the complete system is up and running, this data will be available from regions of the atmosphere up to 85km high.

The radar system, which operates at a frequency of 46.5MHz, can detect not just wind speed, but everything from small-scale atmospheric phenomena such as turbulence, right up to weather fronts and the jet stream. All this information is vital for the aviation industry, both for hazard avoidance and for route planning to reduce fuel consumption.

Professor Lance Thomas of the University College of Wales, Aberystwyth and Dr Tony Hall and Dr David Llewellyn-Jones of the Rutherford Appleton Laboratory say (*SERC Bulletin* Vol. 4 No 2) that the new facility is expected to yield valuable research information, particularly when its results are compared with data from lidar atmospheric probes operated by UCW's physics department. Already the new radar has attracted considerable interest from abroad, notably Japan.



SERC's giant VHF radar array, which will probe the Earth's middle atmosphere. Each Yagi stands 5m high.

Health plug: biological effects of power lines

Of all the tantalizing questions that obstinately refuse to go away, the effect of ELF electric and magnetic fields on health is perhaps the most persistent. It's been debated on and off ever since the 1960s, always with inconclusive results. Pylons, like toxic waste, are highly susceptible to the Nimby ("Not in my back yard") principle, but are highly resistant to any attempts to prove them dangerous.

As previously reported in these pages (February 1988, page 173), one of the biggest epidemiological studies, the New York State Power Lines Project, concluded in July 1989 that the health risk to people living under cables was either small or non-existent. Yet the study did acknowledge the existence of clusters of excess leukaemia cases in a few places only.

Common sense would of course tend to rebut any suggestion that 50 or 60Hz fields carry a health risk. In the first place, the amount of energy entering the body is substantially less than that which flows around naturally in nerve and muscles. In the second place there has been no widespread rise in disease since the introduction of electricity for domestic and industrial purposes. Yet laboratory studies have demonstrated changes in the genetic chemical DNA and in the ways other chemicals flow across cell membranes. Unfortunately such studies haven't always produced consistent results, nor is it easy to extrapolate from cell cultures to people.

Almost as if to keep the proverbial pot boiling, the US Office of Technology Assessment (OTA) has now released a study commissioned from Carnegie-Mellon University showing that if overhead power lines are harmful, then domestic wiring and appliances are infinitely worse. This study (Nair, Morgan and Florig – Biological Effects of Power Frequency Electric and Magnetic Fields – OTA) suggests that home is where most exposure occurs. This is partly because of the proximity of domestic wiring and partly a consequence of the time spent near it. So it seems as if any effects of pylons and overhead cables are probably more a result of their architectural impact than their associated electrical and magnetic fields. But where does the OTA study leave the overall question of ELF fields and health?

As before, there doesn't seem to be much real progress. Overall, says the report, the evidence now available is too weak to allow firm conclusions either way. It does, though, call for further detailed studies into the type of exposure. Could it be, for example, that infrequent explosure to high fields for a short time is more significant than long-term exposure to lower fields? Only animal tests and more epidemiological studies will tell.

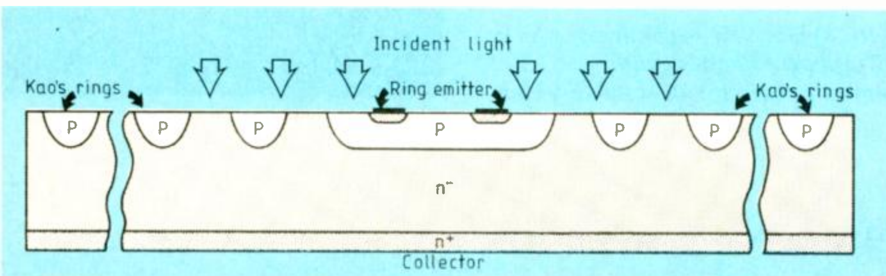
Hedging its bets, the OTA study suggests one practical approach that would be to adopt a "prudent avoidance strategy". Translating into English, I think that means don't sit near cables unless it costs money to sit elsewhere.

Research at Philips

Always a good read is the annual review of Philips Research Laboratories (formerly the Mullard Research Laboratories) in Redhill. The most recent (1988) edition contains among other things a fascinating study into the practical limits of infra-red as a means of data communication between computer peripherals. Did you know, for example, that the worst source of interference is the modern Rf-driven fluorescent lamp which radiates modulated IR up to frequencies of several hundred kHz? Philips complains that a hazard to the growth of IR equipment is in fact a lack of international standards controlling the radiation of spurious infra-red.

Another paper in the same Annual Review describes the development of a 3kV bipolar photo-transistor – not as you might imagine a laboratory curiosity but a device that could make easy the stabilization of CRT electrode voltages or the driving of electrostatic loudspeakers. **Figure 1** illustrates the structure of the transistor which features a ring emitter for high light sensitivity and several concentric p-doped structures called Kao's rings. These can easily be created using planar techniques and, as well as increasing the photosensitivity of the transistor, also guard against breakdown. Typical devices have BV_{ceo} of 3kV and BV_{cbo} of 4kV.

One of the first practical uses of these photo-transistors has been in an amplifier designed by Philips Central Research Laboratories at Eindhoven in Holland. **Figure 2** shows the essential elements of an all-solid state driver circuit for electrostatic loudspeakers. Using a push-pull configuration with four photo-transistors in each half working as opto-couplers, the amplifier can easily deliver 20 watts outut at a voltage swing of 8kV! This performance could have been achieved with fewer devices, but eight are used to guard against unequal voltage distribution. Clearly the days are long gone when you could safely stick your fingers inside solid-state equipment!



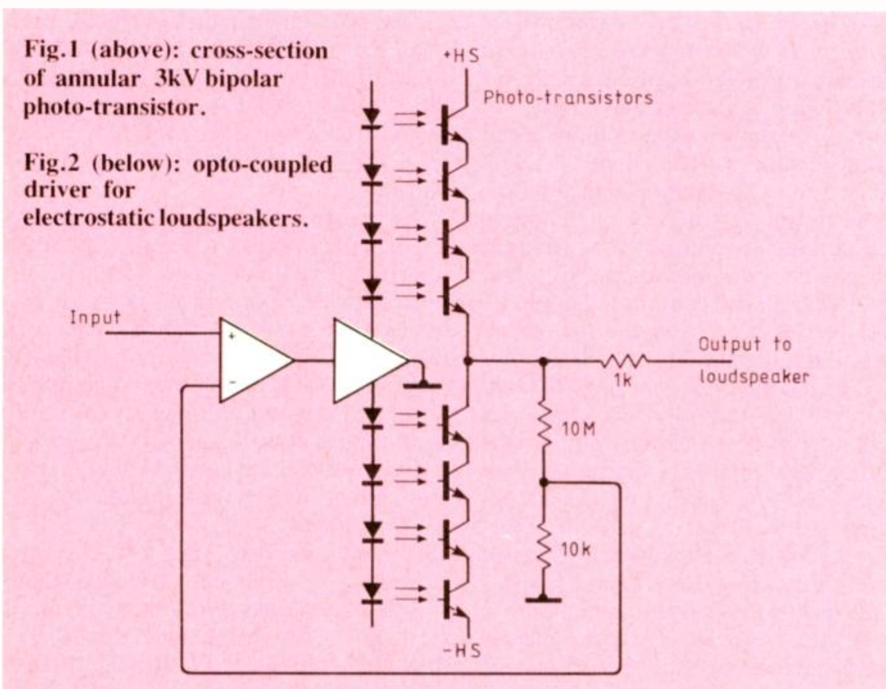


Fig.1 (above): cross-section of annular 3kV bipolar photo-transistor.

Fig.2 (below): opto-coupled driver for electrostatic loudspeakers.

Canine byte?

At the time of writing, Britain's controversial experiment with electronic tagging of remand prisoners is somewhat in the doldrums. But in a less sophisticated and less publicized way, a new method is being tested of keeping tags, not on people but on dogs.

Earlier this year the Battersea Dogs Home conducted successful experiments in implanting coded chips under the skin of several dogs in its care. Now, following veterinary tests, the Home is to implant all of the 10 000 to 15 000 stray pooches that pass through its doors each year. The idea is to identify each dog uniquely and so be able to keep a check on its subsequent progress. Although the Dogs' Home is extremely fastidious in selecting good homes for its inmates, it has had no means up till now of telling, for example, whether a dog was on its first or second visit.

The implant devices are cylindrical in shape, just over 1cm long and 2mm in diameter. Manufactured by Animalcare Ltd, they're read off by a scanner that displays a ten-character alphanumeric code. It is claimed that 34×10^9 unique and unalterable codes are available, more than enough to cope with Britain's estimated quarter of a million stray dogs.

"YOU SHOULD BE GLAD YOU WEREN'T IN ON THE TRIALS, SON!"

Clearly there's a significant lobby among animal lovers who'd like to see this sort of electronic tagging used as an obligatory means of registering and identifying all dogs, as is the case with guard dogs in the Irish Republic. I must admit though, bearing in mind the latest experiments to tag remand prisoners, that such technology might well find a use for species other than canines – both sides of the border.

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

SOLID-STATE AUDIO POWER

John Linsley Hood traces the evolution of transistor audio power amplifiers from 1956 to the present day. Designs produced up to 1975, covered in this first part, reached a high standard, but still contained residual design mistakes

Valve audio amplifiers generally require an output coupling transformer to match the output impedance to that of the loudspeaker load. If a good performance is sought, this component will be expensive and bulky. The savings in cost and bulk which are possible and the improvement in performance, especially at the extreme ends of the audio spectrum, by avoiding the need for this component have remained one of the major benefits of "solid-state" circuitry.

Early transistor audio amplifiers

Understandably, early designs in this field owed a lot to previous valve amplifier practice, with transformer interstage coupling being used to allow a push-pull output configuration. However, the real break-through in this field came with the introduction, in 1956, of the "quasi-complementary" output stage due to H.C. Lin[1], of which the basic circuit layout is shown in **Fig. 1**.

At the time, the most easily obtained transistors were germanium diffused-junction p-n-p devices, although some germanium n-p-n transistors were becoming available in low-power versions. The attractive feature of Lin's design was that the circuit provided a push-pull output without the need for a coupling transformer, and with a pair of output transistors which were both of the same type. In addition, it only required one low-power n-p-n device.

The performance of this circuit was excellent by contemporary transistor audio-amplifier standards, in that it had a 30Hz – 15kHz bandwidth and a full-output-power THD figure of less than 1% at 1kHz, which decreased somewhat with decreasing output power. However, germanium transistors have too high a temperature coefficient of leakage current for them to be suitable for domestic use, where thermal runaway could never be completely ruled out.

Sadly, the relative excellence of the Lin circuit, which was designed around germanium transistors, gave misleading encouragement to other engineers, on a world-wide basis, who translated the design into silicon-transistor-based versions when, during the early 1960s, n-p-n silicon planar power transistors became available.

The inherent snag in this approach is that the base voltage/collector current characteristics of germanium and silicon transistors are different, with that of the silicon device being much more abrupt, as shown in **Fig. 2.**

Moreover, since the permissible thermal dissipations of the output devices were then fairly limited – by comparison with valves – it was necessary to operate the output stages at a fairly low quiescent current, in class AB, or even (with zero quiescent current) in class B. High (notional) levels of negative feedback were then used to lessen the residual distortion which this incurred.

This design philosophy had the unfortunate effect of maximizing the performance penalties, in that the high levels of NFB inevitably contributed to poor overall loop-stability margins while, at the "crossover" point, the effective gain of the output devices was low or even zero, so that the NFB was ineffective in reducing the distortion at the very point where it would have been useful.

Also, because of the basic asymmetry of the "quasi-complementary" output stage, as shown in **Fig. 3**, not only was the residual inherent distortion large, but it tended to increase as the output power level was reduced, as shown in **Fig. 4.**

This meant that a manufacturer's specification which claimed, for example, "better than 0.05% THD at full output power" might be quite irrelevant to the user, who might have to put up with ten times this amount of distortion at his normal listening levels.

Moreover, the residual distortion, especially at low powers, was rich in dissonant harmonics, which were alien to the normal experience of the human

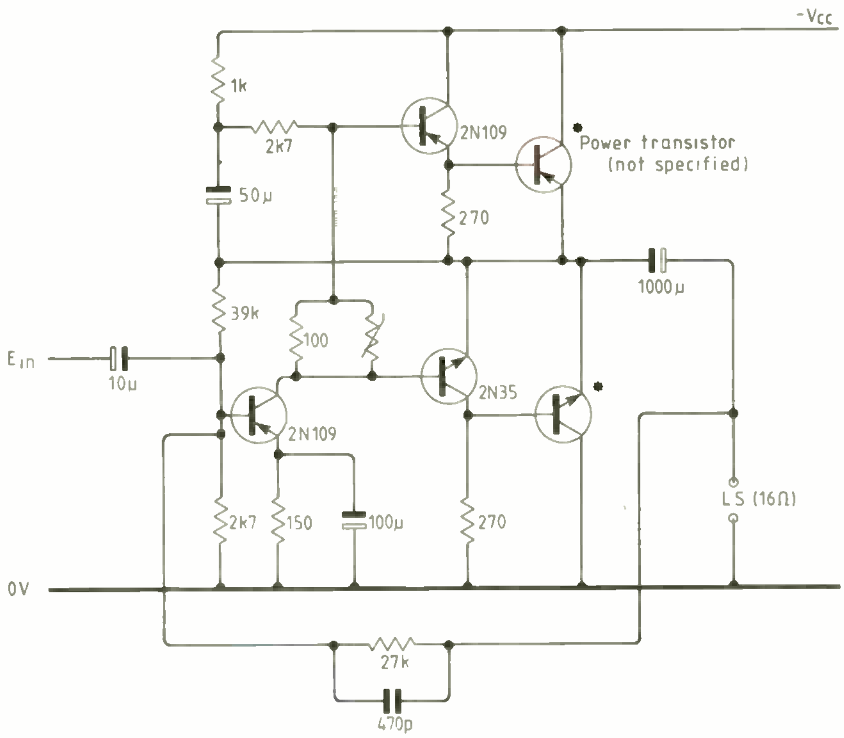


Fig. 1. Original quasi-complementary transistor power amplifier by H.C. Lin, from 1956.

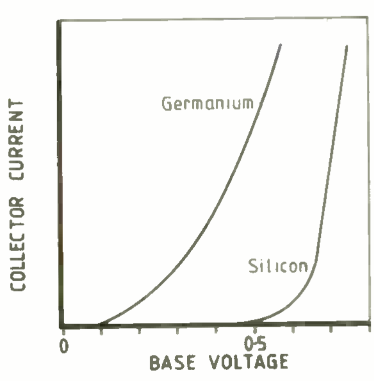


Fig. 2. Comparison of silicon and germanium base-voltage/collector-current curves at 25°C.

ear. In addition, the reduced gain at the point at which the signal waveform crossed the zero axis tended to suppress low-level signal components and give the amplifier a "thin" sound, lacking in "warmth" and "richness".

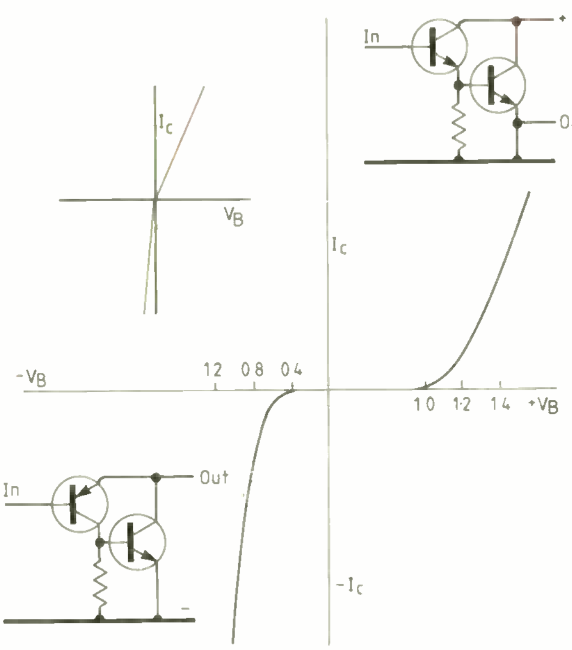
It was hardly surprising, therefore, that these early silicon-transistor quasi-complementary "high-fidelity" designs won few friends among their users. More regrettably in the long term, this unfortunate and temporary lapse of design standards has led to two breakaway movements among the 'hi-fi' community: the "all specifications are meaningless, so only believe your ears" fraternity, and the "back to valves" brigade.

Improved output-stage configurations

There were, in the 1960s, three practicable options for improving the performance of audio-output stages: to use fully complementary output devices, which were just becoming commercially available; to use the output devices in class A; or to modify the quasi-complementary arrangement so that it gave greater symmetry in the two halves.

The first of these approaches was adopted, soon after suitable devices became available, by Locanthi[2] and Bailey[3]. The output stages of a 30W per channel design due to Bailey are shown in Fig. 5.

There are two difficulties inherent in this approach, of which the first is that the p-n-p output devices were, at that time – and to some extent even today –



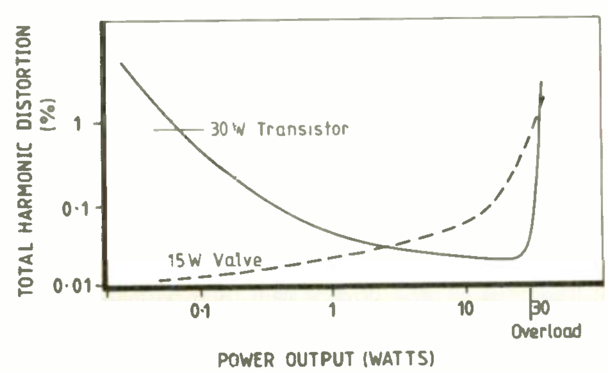


Fig. 3. Asymmetry of silicon quasi-complementary pair. Small diagram shows crossover characteristic when pair optimally biased.

Fig. 4. Asymmetry of early silicon quasi-complementary amplifiers shown in Fig. 3 gave rise to increasing cross-over distortion at low power levels, in contrast with the behaviour of a good-quality valve amplifier.

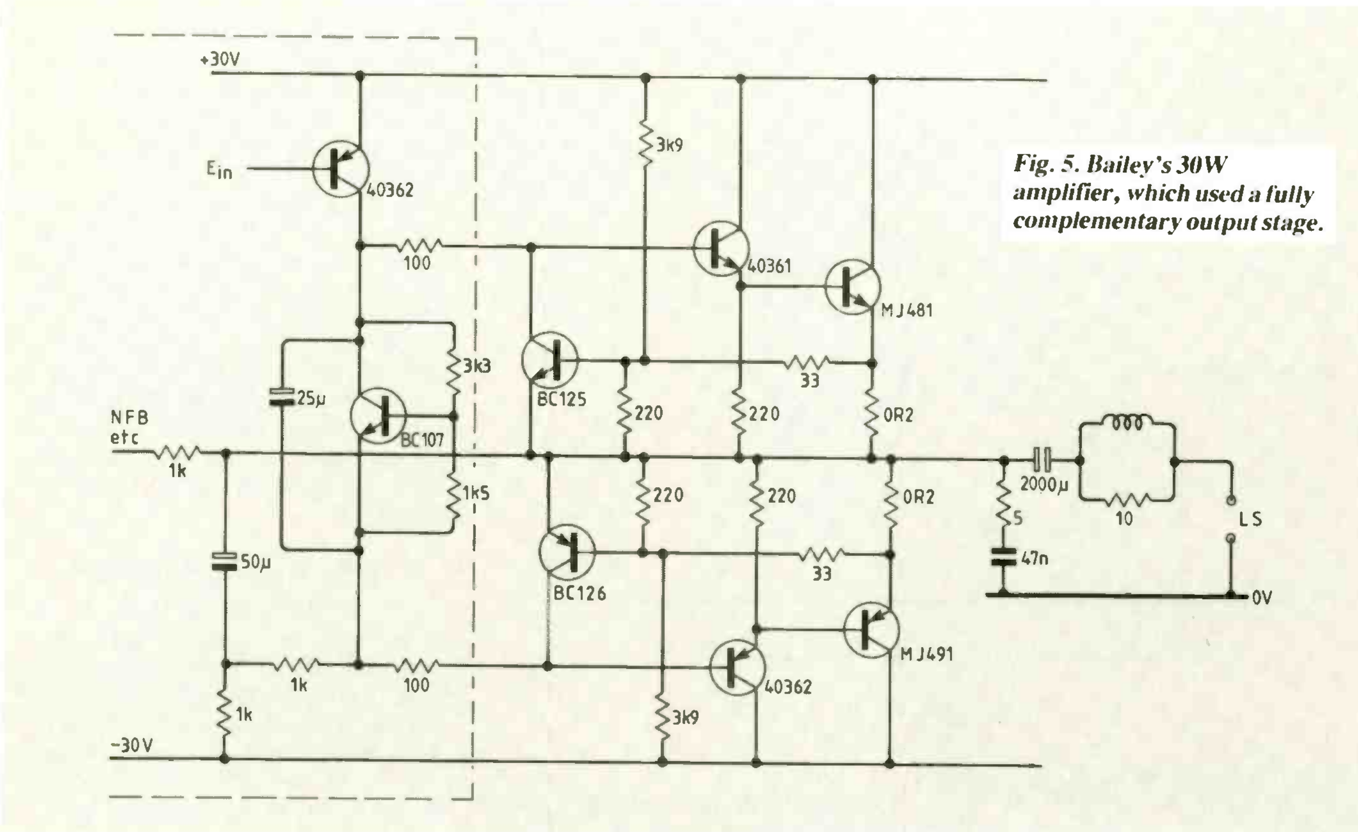


Fig. 5. Bailey's 30W amplifier, which used a fully complementary output stage.

rather more fragile than their nominal n-p-n equivalents, which prompted Bailey to evolve an effective overload protection circuit, also shown in the diagram.

The second problem is that, because of the different majority carriers in the two transistor forms, p-n-p devices tend to have a lower HF transition frequency than equivalent n-p-n ones. The difference in the transition frequencies of the "complementary" output transistors leads to asymmetry of the output stage at higher audio frequencies, with a consequent worsening of crossover and other distortion characteristics.

At that time my own preference, provided that the power requirement was relatively modest, was for the use of class A operation, and a circuit for a 10W power amplifier using this philosophy[4] is shown in **Fig. 6**. This is not a push-pull system, and is therefore intrinsically free from crossover problems. This particular circuit can be visualized either as a simple transistor gain stage with an active collector load, or as an emitter follower with an active emitter load. A difficulty in the use of this layout is that it has a low overall efficiency and is not easily extended in power without the use of a bridge configuration.

The third approach is exemplified by a neat circuit adaptation due to Shaw[5], in which an added diode is used to lessen the differences between the upper and lower halves of the output pair, as shown in **Fig. 7(a)**. Because the output transistors can then be of identical type (and F_t), the worsening of THD with increase in frequency can be lessened.

Baxandall, following an analysis of this problem[6], suggested an elegant circuit improvement, shown in Fig. 7(b), which almost completely eliminates the dissimilarity between the upper and lower halves of the output stage, and allows a low-distortion design to be made with identical output transistor types.

For a subsequent higher-power amplifier design[7], I followed in the footsteps of Shaw and Baxandall, with the circuit layout shown in Fig. 7(c), in which I had added a small capacitor to the resistor/diode network to simulate the effect of the output transistor base/emitter capacitance.

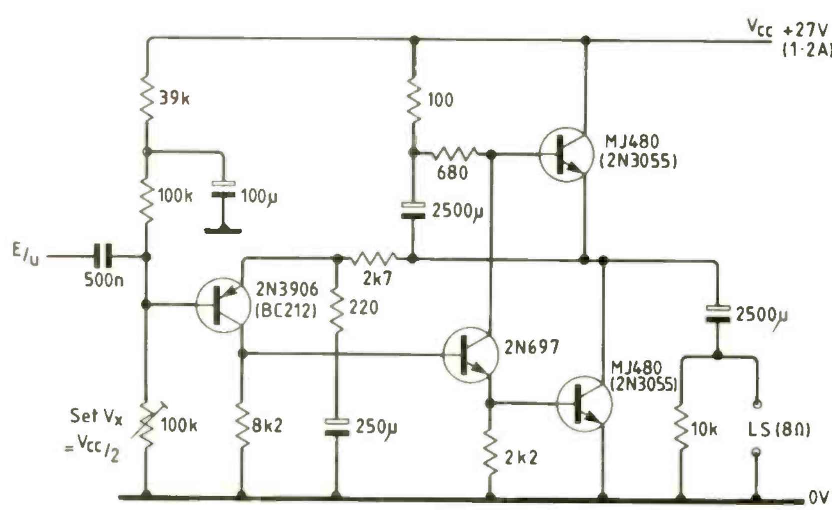


Fig. 6. Author's 1969 10W class A amplifier. Since the operation is not push-pull, there is no crossover distortion.

An alternative arrangement, introduced commercially by the Acoustical Manufacturing Co.[8] in their Quad 303 power amplifier, employed a pair of quasi-complementary triplets, of the type shown in **Fig. 8**. This generates a

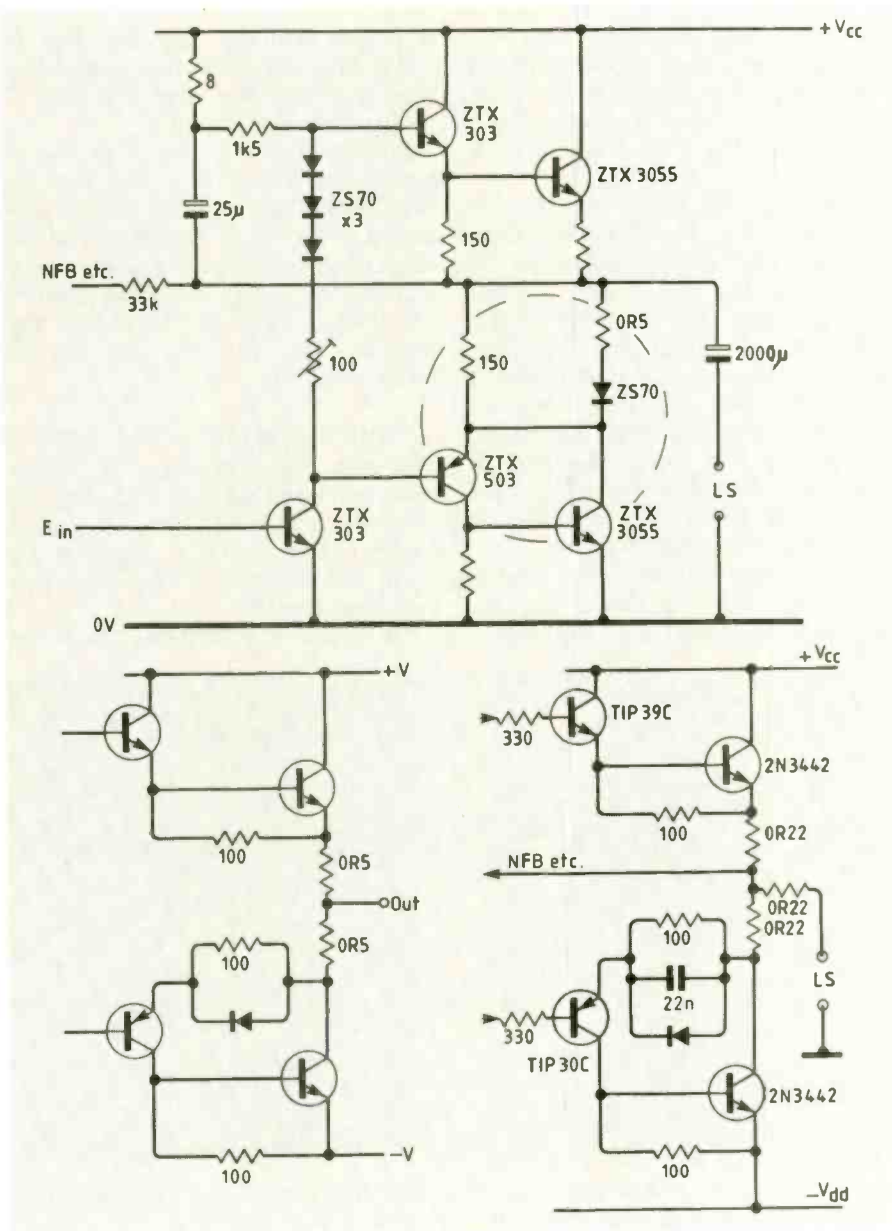


Fig. 7. Shaw's improved quasi-complementary design from 1969, which used a diode to improve symmetry, is seen at (a). At (b), Baxandall's variation further improves symmetry, and (c) shows author's use of small capacitor to simulate effect of base/emitter capacitance.

high internal loop gain within each of the compound output emitter-follower groups, which helps to minimize the asymmetry of the output stage "halves" and the residual crossover distortion which this asymmetry introduces.

Other layouts have been proposed to improve symmetry in such quasi-complementary pairs, such as that due to Visch[9] and Stevens[10], but contemporary high-quality design appears to be exclusively committed to symmetrical layout employing using complementary transistors, which use either the output transistor configuration shown in Fig. 5, or that of a symmetrical compound emitter follower of the type shown in **Fig. 9**. This has the advantage that the base/emitter junctions of the output devices, which will get hot, are not included in that part of the circuit which determines their forward bias, which offers better output-stage quiescent current stability.

All of these class AB circuit layouts require that the quiescent current in the output stage remains close to some optimum value if the target performance of the design is to be achieved, in spite of changes in the temperature and age of the components. This has been the subject of considerable circuit development, of which some radical approaches are discussed later.

With an eye on their use as output devices, several manufacturers have introduced low-cost, high-specification, monolithic, Darlington-connected output transistors, having the internal structure shown in **Fig. 10.** However, because the driver transistor is on the same chip as the output device and is heated by it, the use of such output transistors makes output-stage quiescent-current stability more difficult to achieve.

Direct-coupled layouts

All of the earlier "transformerless" transistor power amplifier layouts were designed to operate between the 0V rail and some single positive (or negative) supply line, with a DC blocking capacitor to the loudspeaker, using a layout similar to that shown in **Fig. 6.** This

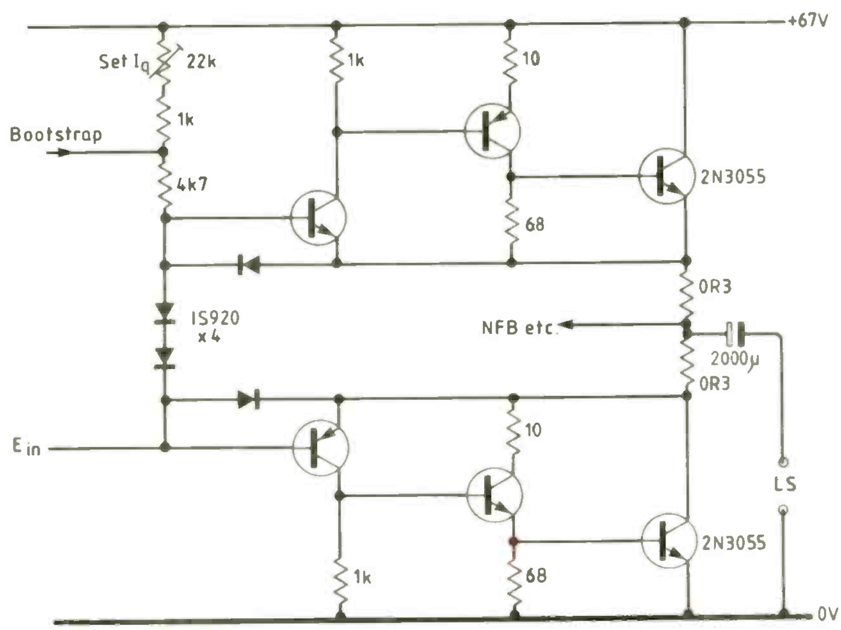


Fig. 8. Quad 303 quasi-complementary triplets.

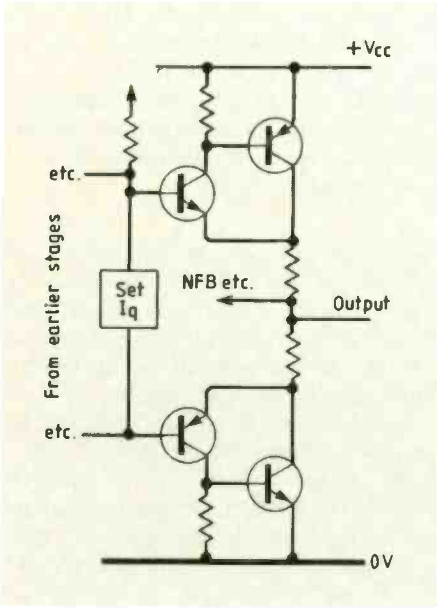


Fig. 9. Symmetrical compound emitter-follower. Bias is less temperature-dependent.

meant that the loudspeaker unit was protected from damage in the event of a semiconductor failure, but involved the use of a large-value coupling capacitor if an extended low-frequency response was sought.

However, designers became increasingly convinced that there were advantages in sound quality to be obtained by the use of the so-called direct-coupled layout, of the type shown in **Fig. 11,** in which the amplifier operated between a pair of symmetrical (±) supply lines, so that there was no longer a need for the output capacitor. This layout added the problems of LS protection – most easily provided by a simple output fuse – and the stability of the nominally 0V output potential.

Various input circuit layouts have been proposed[3,11] to ensure that no residual DC appeared at the loudspeaker output terminals, but the simplest and most direct solution to this problem is the use of an input long-tailed pair of the kind shown in **Fig. 12.**

Provided that the emitter currents of both devices are the same, and that they have similar values of current gain, the output offset will be close to zero if the base circuit resistances for both transistors are the same. A high-impedance tail load is desirable to ensure the integrity of signal transfer between the two input halves.

Gain stage circuit designs

The gain stages between the signal-input point and the output devices are normally operated in class A and are configured to provide as wide a bandwidth, as high a gain and as low a phase shift as practicable.

To simplify loop-stability problems,

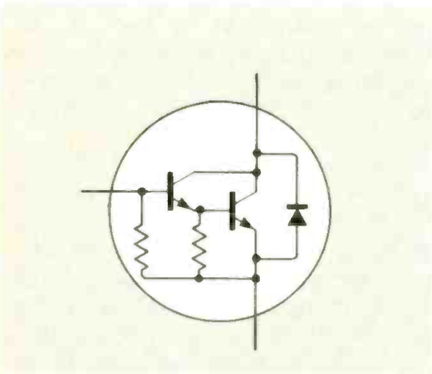


Fig. 10. Internal structure of n-p-n Darlington transistor.

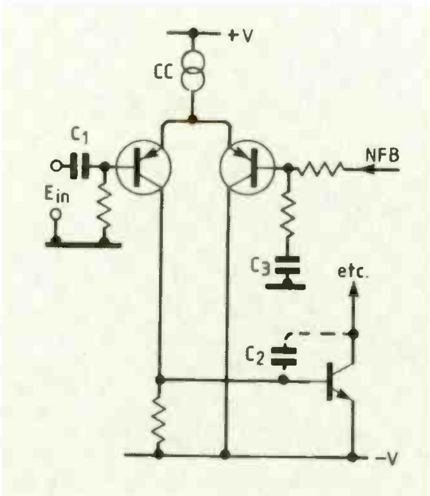


Fig. 12. Long-tailed-pair input circuit ensures that no DC is present at output.

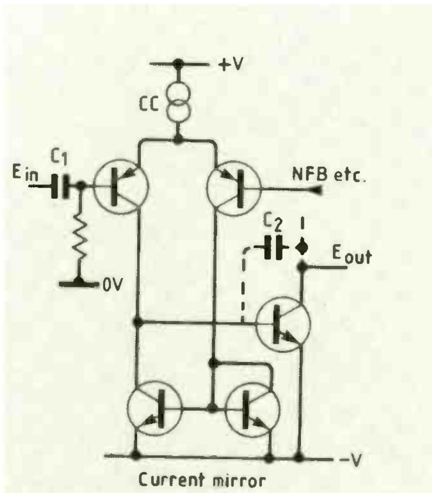


Fig. 13. Current mirror presents high dynamic-impedance load.

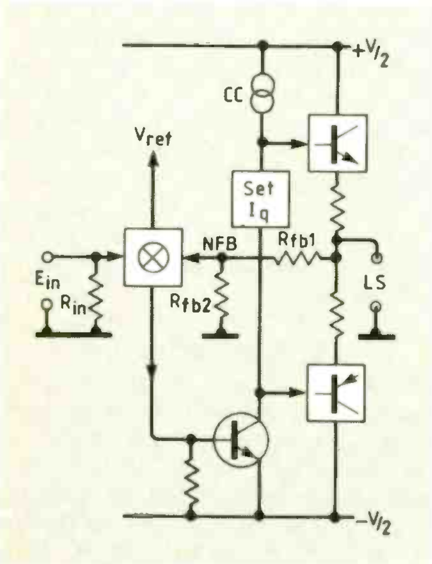


Fig. 11. Use of symmetrical supplies avoids need for blocking capacitor.

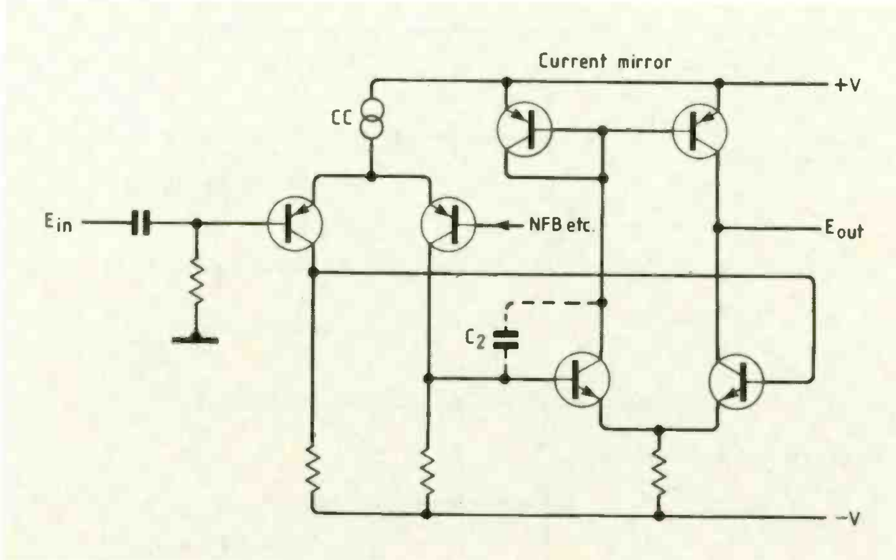


Fig. 14. Current-mirror shifted to second stage, as used in ICs by National Semiconductor and by Hitachi in an audio power amplifier.

the gain block is normally restricted to two stages and, to get as high a gain as possible, the collector load for the second stage has as high a dynamic impedance as practicable. This is often a "bootstrapped" load resistor, as employed in the designs of Figs 5 and 6. However, in more recent circuits, a constant-current source load is normally used, since this gives rather better distortion characteristics, especially at LF, though the possible total output voltage swing may be rather less.

The load for this input stage may just be a single resistor, in the first collector circuit, as shown in Fig. 12 although, following the practice in IC op-amps, it is more common to use a current mirror in this position, as shown in **Fig. 13**.

An interesting development of this idea is to move the current mirror to the position of load for the second gain stage, as shown schematically in **Fig. 14**. This is an idea which appears to be due to National Semiconductor and is employed in several of its IC op-amp designs, such as the LH0061. This has been adapted, more recently, to an amplifer circuit by Hitachi.[12]

Loop stability and transient intermodulation distortion

If negative feedback is applied around a circuit enclosing a two-stage gain block as well as an output emitter-follower system, it is probable that the total phase shift within the loop will be 180° at some frequency at which the gain is unity, and the amplifier will oscillate.

It is essential, therefore, to ensure stability by causing the open-loop gain to fall as the frequency approaches the upper (or lower) 180° phase-shift points. With most direct-coupled circuits, the LF loop phase shift will not exceed a safe value; stability problems are therefore confined to the HF end of the pass-band.

It was, and is, customary to achieve HF loop stabilization by imposing a single-pole dominant-lag characteristic on the system by connecting a small capacitor between base and collector of the second gain stage (C_2 in Figs. 12, 13 and 14), since this arrangement gives the best THD performance at high frequencies. However, this approach leads to the problem that it imposes a finite speed of response on the second gain stage while C_2 charges or discharges through its associated base and collector circuits.

If a composite signal including a step waveform is then applied to the input device, it is possible for the input stage to be driven into overload because no compensating feedback signal has yet had time to arrive from the subsequent amplifying stages. This can lead to a complete loss of signal during the period in which the second gain stage is paralysed, and caused Otala[13] to apply the term "transient intermodulation distortion" to the perceived acoustic effect.

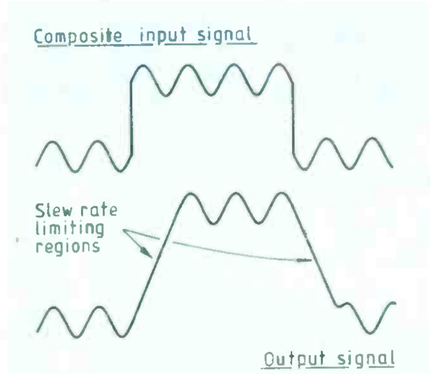


Fig. 15. Effect of slew-rate limiting.

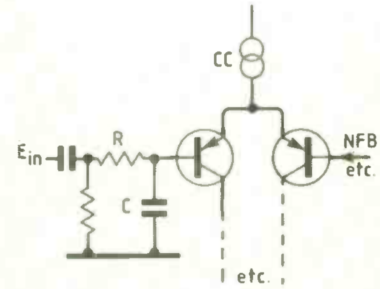


Fig. 16. Input RC filter restricts rate of input voltage change to that of rest of circuitry.

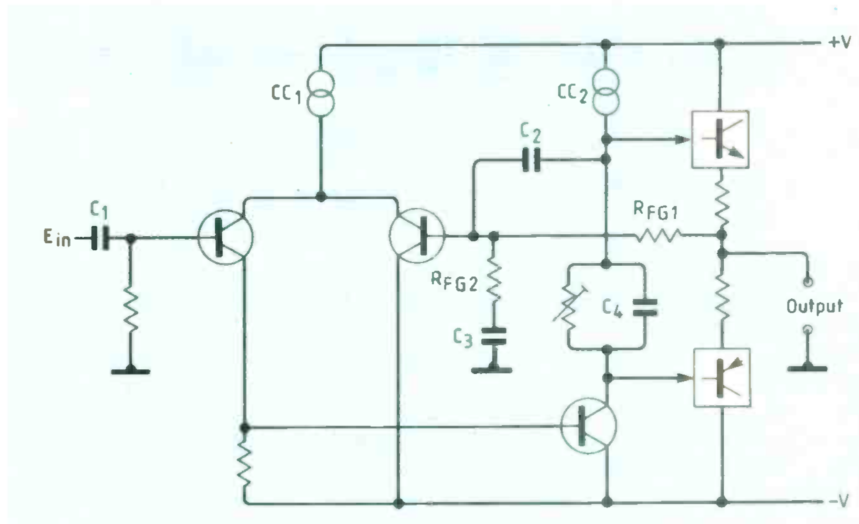
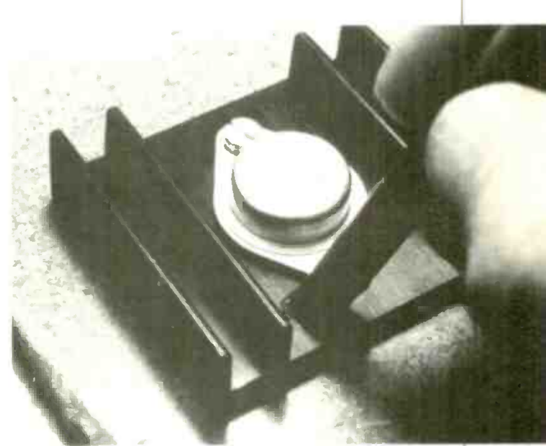


Fig. 17. Preferred position for HF loop compensation capacitor.

A simpler description suggested by Jung[14] is "slewing-induced distortion" (or slew-rate limiting) and this defect in the amplifier performance is clearly visible on an oscilloscope display, with an appropriate composite input signal, as shown in **Fig. 15**.

This defect is, however, not an inevitable consequence of dominant-lag compensation, since there are ways of avoiding it[15]. Of these the simplest is just to introduce an RC low-pass network at the beginning of the amplifier to restrict the rate of change of input signal voltage, as shown in **Fig. 16**.

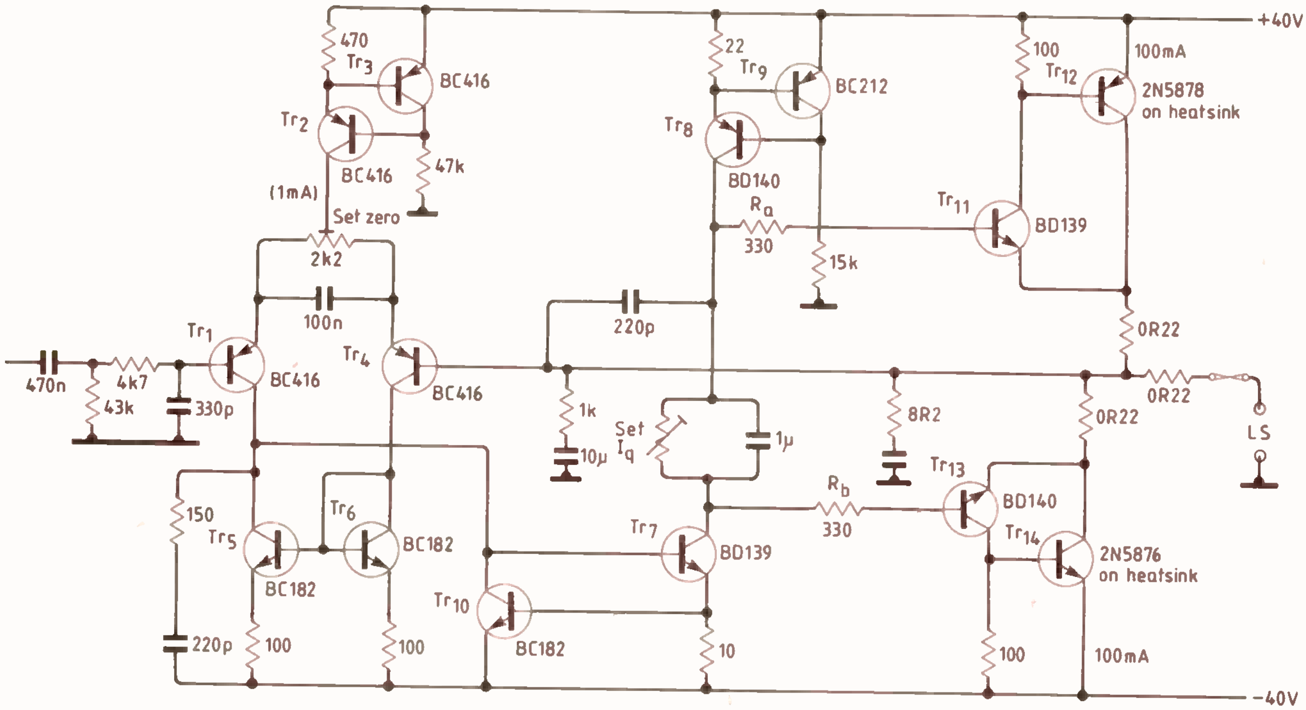
A better alternative is to include the whole of the gain stages within the bandwidth-limiting system, as used, for



example, by Bailey[5] and as illustrated in **Fig. 17**. Placing C_2 in this position avoids the possibility of input-device overload as a consequence of the sluggishness of response of later stages.

Other snags

A typical amplifier might, therefore, have the kind of circuit shown in **Fig. 18** (resistors R_a and R_b avoid "latch-up").



Some temperature compensation for the output transistor forward bias can be obtained from a suitable degree of thermal contact between the output devices and Tr_9.

The stray capacitances associated with the collector circuit of Tr_7 will impose a maximum slewing rate on a positive-going voltage excursion. The collector current of Tr_7 must therefore be adequate to keep this slewing rate sufficiently high. With this point in mind, several designers, such as Bongiorno[16,17] and Borbely[18], have offered fully symmetrical amplifier circuits of the form shown in **Fig. 19**, so that the maximum practicable rate of change of signal voltage at the gain-stage output is not limited by the final driver-stage constant-current source load.

However, it is more difficult to maintain a stable value of output-stage quiescent current with this type of circuit layout, and this has discouraged its more widespread adoption.

Fig. 18. Typical fully complementary audio power amplifier, incorporating the features discussed. Slew rate is limited by Tr_7 collector current.

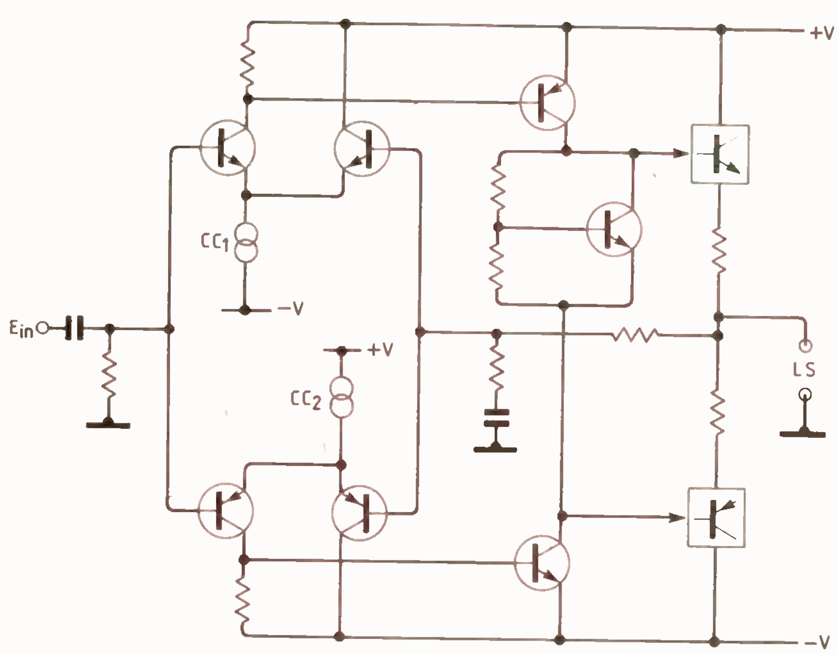


Fig. 19. Driver stage by Bongiorno, which does not suffer from limitation of Fig. 18 circuit.

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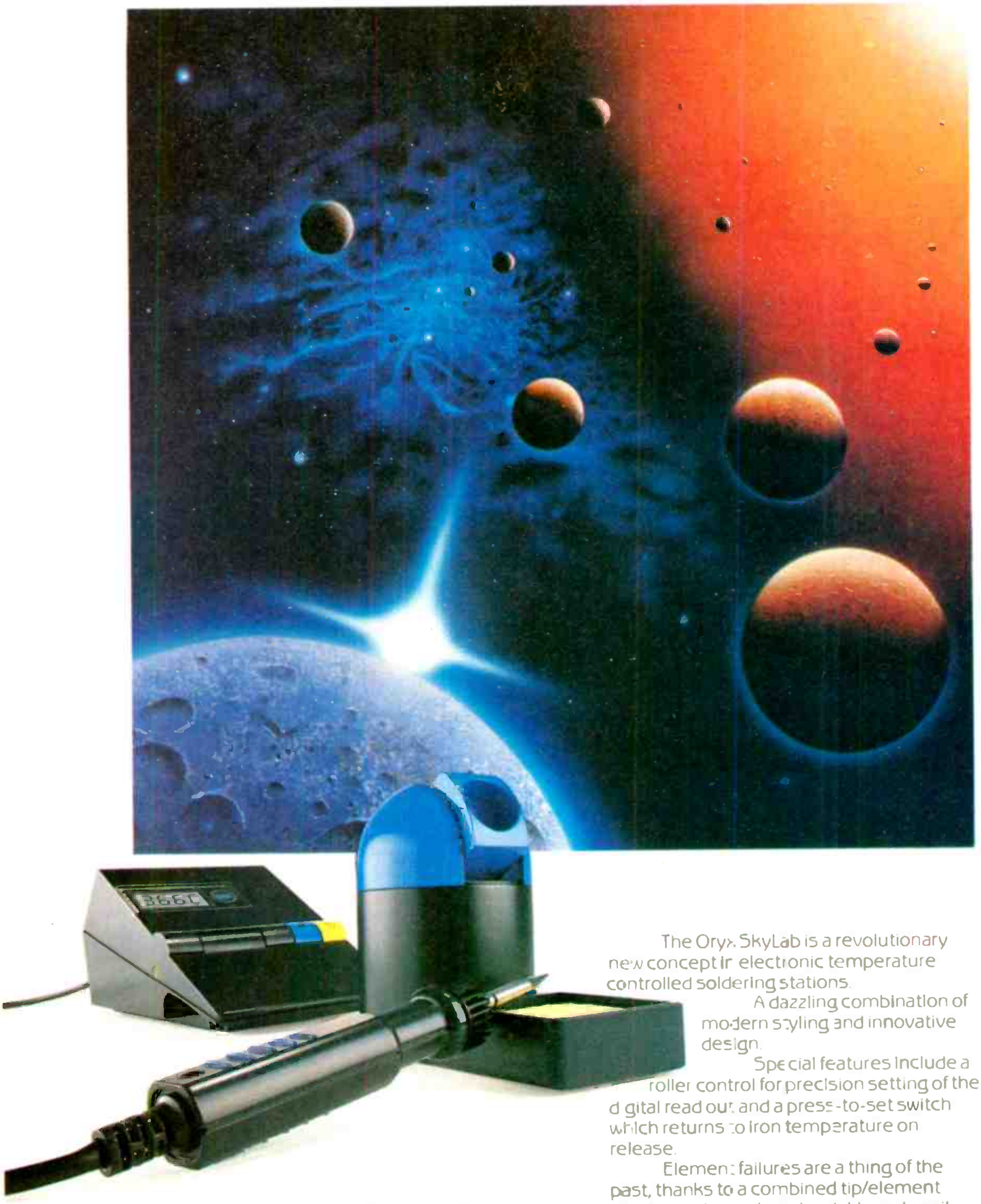


66mips controller

Intel's latest 32-bit micro will execute an average of two instructions for every cycle of its 33MHz, an integer performance of 66mips.

The 80960-CA is aimed squarely at the embedded control market, although the device architecture strongly resembles a risc-based general purpose microprocessor. However, unlike the 860 device launched earlier in the year, there are no floating-point architectural features. To compensate, it can execute up to three non-conflicting integer instructions simultaneously. This makes it particularly suited to real-time task handling. It can achieve a complete context-switch on interrupt in less than 800ns.

The new device maintains complete software compatability with the 16MHz 960-KA version announced last year. However, because the CA version runs at twice the speed and can execute many of its instructions in parallel, Intel says that the new processor can run applications some five times faster without any code changes in the software.

The device incorporates separate 1K caches for data and program looping while register scoreboarding permits parallel instruction execution.

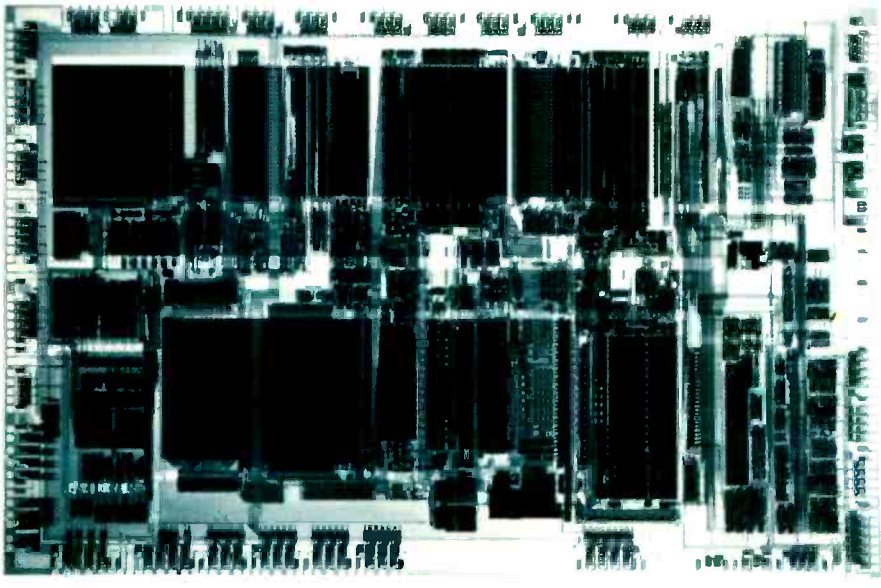
Memory handling is of particular interest. The CPU can be programmed to recognize up to 16 key memory segments in the address space. Each can be made to associate the number of wait states required for access and data transfer. Even the bus protocol can automatically adapt itself to the type of memory attached to the sector. This allows widely differing types of memory to be attached directly to the main processor without extra hardware.

The other big player in the 32-bit embedded control market, Hitachi, has opted for cisc type architecture by offering enormous numbers of general-purpose registers as an alternative to cached parallel operation. Hitachi says that the H16 series, which can include familar items such as I/O peripherals, counter/timers and A-to-D on chip, is optimized for control applications written in high-level languages.

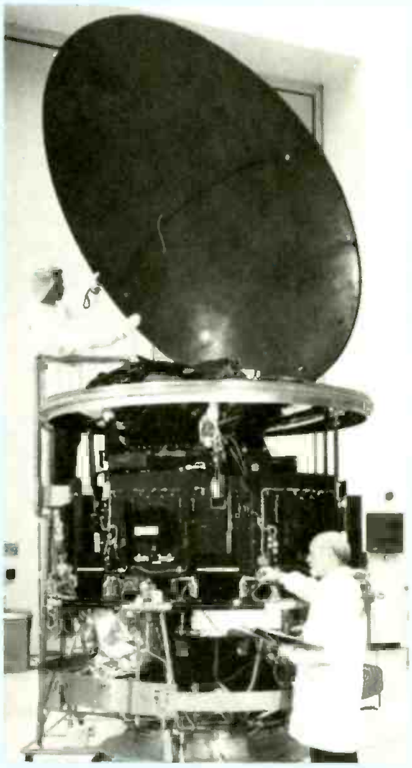
Intel has an optimizing C compiler available for the 960 series.

The 960-CA fits Intel's view of the up-market microprocessor business in that applications divide into three specific areas: micro engined minicomputers (860) general business machines (the dos-based 486 chips) and real-time embedded control (960). Although the instruction sets are incompatible between devices, each has been optimized for its area of service. Furthermore, the Intel CHMOS 1μm process used across the board is generally considered to bestow excellent performance.

The company says that around half the 32-bit embedded processor market goes into disk drive products, the rest going into laser printers, communications and military usage. It expects 32-bit volumes to increase from 1.5 million units currently to 21M by 1993.



Upwards but onwards?



Technicians inspect Marcopolo I, the satellite carrying BSB's television transmitter before its successful launch at the end of last August. This has been the only fruitful aspect of the BSB venture to date. The company looks as though it will have to ditch plans to offer its subscribers a flate plate aerial system for use with the satellite. More seriously ITT Semiconductors, supplier of the mac decoder chipset needed for BSB, have yet to deliver devices in any quantity to the set manufacturers.

Colby's Column

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NEW GENERATION DATA LOGGING

A new hand-held intelligent Data Logger form Rustrak Recorders, the RUSTRAK RANGER, has 8 storage channels for a wide range of sensors, AC/DC, or digital (pulse) signal combinations, plus 4 channels for programmable mathematical functions using values derived from signal input. Measurement of Real Power for mains monitoring is now made possible and rates such as wind speed, flow etc can be calculated for scientific/environmental data · collection. Other features include interchangeable data packs with automatic memory writing allowing data collection to be prolonged indefinitely. Full spec. from me.

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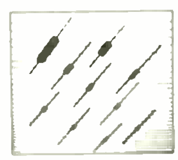
HIGH STABILITY AT LOW COST

Where time and temperature stability combined with low component cost contribution to the final equipment are rated paramount, VISHAY-MANN have designed a new range of Small Precision Wirewound Resistors for industrial and commercial applications. Designated AX100, AX150, AX205 and AX210, with electrical properties of TCRs 10PPM/°C to 3PPM/°C; stability of 0.005%per year; resistance range from 5R to 1.3 megohm; size range from 8mm x 4mm for AX100 to 12.7mm x 6.5mm for AX210. For further details of these high precision, low cost resistors contact me.



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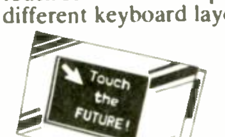
Available now from Perdix Components, the DENSITRON TOUCH TERMINAL is a uniquely flexible and intelligent solution to the interface between man and machine. The D.T.T. contains an infra-red touch sensitive A.C. plasma display onto which may be configured 130 different keyboard layouts. It also features a 286 processor with 128K of user RAM together with 82786 graphic display processor. Communication to the host is via a RS232 or RS485 serial port and a standard keyboard can be connected to the terminal. I can let you have full details.



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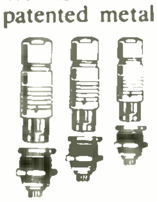

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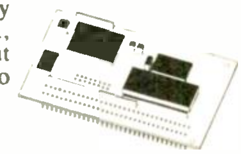
. . . a computer card form Triangle Digital Services intended for building into your products. By putting software for the application into PROM the TDS9090 Contol Computer starts to run as soon as power is applied. Attach 64 keyboard, LCD and I^2C bus peripherals. There are on card EEPROM, 2 serial ports, 35 parallel input-outputs, 30K bytes, RAM, 16K dictionary RAM/PROM, 256 bytes EEPROM, 16K, Forth and smaller size - 100mm x72mm. But there is much more to TDS9090 than that, so ask me for the whole story.



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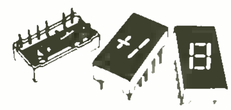
To achieve high light emission from low input, Selectronic's LOW CURRENT LED DISPLAYS utilise GaAsP LED chips on transparent GaP substrate. Character heights 0.3" - 0.8" with consistent illumination between displays, categorised for intensisty, pin configuration is as standard LED. 7 segment and universal +-1, typical consumption is 3MW/SEG at 2 MA drive. Depending on display size viewing is from 2-7 metres with excellent character appearance, making it particularly suitable for instrumentation, P.O.S. and meters. PCB or socket mounting, IC compatible, TL1 300UCD/SEG at 2MA. Full information from me. *Reader enquiry no. 125*



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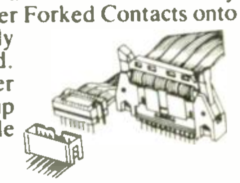
All requirements for direct/indirect insertable flexible connection to PCB headers are met by Assmann Electronics' MULTIFLEX Insulation Displacement Connectors. The flat cable system uses UL94 approved moulding material to 224 standards and contact is made by displacing the insulation with Beryllium Copper Forked Contacts onto the conductor, giving a gas-tight joint. Mostly ex-stock, UK made and competitively priced. Other Assmann specialities: sockets, header latched and low profile, transition plugs, dip plugs with/without strain relief and cable harness. Ask me for full details.



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FIBRE OPTIC TERMINATIONS

OPTALL Fibre Optic Connectors from Radiall Microwave Components offer complete and rapid termination systems coupled with ease of assembly; their F-SMA FAST 905 906 Series, using crimp and cleave techniques, allows assembly in about 1' 30". The range is wide, running into 9 basic types and many sub-versions, including High Performance 'Optaball' System. The F709 Series is ST compatible and the MP Series is designed for polarization maintaining fibre. Comprehensive termination tooling kits are available and most items are ex-stock or via distribution. Detailed literature available from me.

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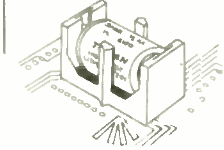
RETAINING THE RIGHT CONTACTS

Eliminating the need for batteries to be soldered directly to the PCB, The principle benefit of the SPEARETTE Battery Holder is good, highly reliable contact together with high retention force under the most arduous conditions. Moulded in high strength acetal resin for AAA, AA, 1/2AA AND 2/3AA type batteries, the holder is soldered directly into the board and additional retention can be obtained by using hollow rivets or screws. Suggested as typical applications are computer back-up memory, communications equipment and the like. Ask me for full details.



Reader enquiry no 129

Apollo workstation is cheapest yet

A Unix-based workstation at a price comparable with a top-of the range PC: that's the appeal of the new Apollo DN2500 series. The new machine combines a 68030 processor, a 25MHz floating-point processor and integrated networking to make a workstation suitable for applications in CAD, computer-integrated manufacturing and desk-top publishing. Both types of Unix will run on the 2500, which can be linked both to further Apollo workstations and to systems from other manufacturers via industry standard links. Peripherals can be connected via a built-in SCSI bus. The machine can run without its own disks on a network, or with up to 1.2Gbyte of mass storage with one expansion. Its relatively low price, £3400, is made possible by the use of a single mother-board with multiple asics. Over 2000 applications are available to users of the Apollo family, which extends from the new 3.5Mips machine to a 100Mips-plus personal supercomputer. Apollo Computer, which since May 1989 has been a subsidiary of Hewlett Packard, is at Bramley Road, Bletchley, Milton Keynes MK1 1PT; tel. 0908-366188.

High-voltage thermopile

Researchers at Cardiff University have invented a semiconductor process which can integrate a large number of thermocouples on to a single chip delivering 2.5V.

Conventional thermopiles of the sort which powered the Voyager spacecraft use numbers of discrete semiconductor thermocouples to develop relatively low voltages. High voltage thermopiles depend on brittle wire-like structures. The Cardiff researchers have developed a technique using ion implantation allied to other conventional semiconductor fabrication techniques. Each chip measures 0.5cm×0.5cm and delivers 2μW of power.

Playing the Unix game

What are the chances of the average PC user foresaking MS-DOS and becoming a Unix fan?

Not much you might say, or might have said until now, for things are changing fast. Atari is just one of a number of companies offering the enticing prospect of high resolution (OK, relatively high resolution) graphics workstations for under £2000.

Best known in this country as the maker of the games-orientated ST range, Atari has other reputations elsewhere. In West Germany, for example, the ST is better known and respected as a business rather than a games machine. The company's own exhibition there in August was nearly as big as a mainstream PC exhibition here.

It was at this show that Atari launched its new TT Unix box. Based on the Motorola 68030 processor, with 2Mbytes of memory and a 60Mbyte hard disk, it features graphics that are claimed to be about the same quality as VGA on a PC.

The price is the thing which will attract many. This is expected to be around £1900 when it appears here. Keen types can lash out DM5700 in Germany from October.

Atari is not alone in looking at this market. Several Japanese companies are also announcing low-cost Unix systems. Takaoka will have a non-colour graphics machine out for around £1600 soon, though I don't suppose the UK will be the earliest market served.

UK games players will also be interested in the other major announcement from Atari, the upgraded STE. The two main enhancements are an uprated 512 colours displayed, from a palette of 4096, and stereo sound production to a claimed CD quality. Together with a maximum of 4Mbytes of memory (is this a games machine?) it provides a dramatic enhancement to graphics representations.

Reworked Amstrad?

It will be interesting to see if the low prices of the new Unix boxes affects the future of low cost box importer Amstrad. In the short term, the company is trying to get over its hardware problems (see last month) with the expected launch of new 286 and 386-based machines.

These should be more than simple reworking of the 2286 and 2386 machines which had the disk problems. As is the way with numbering systems, the new machines will be known as the 1286 and 1386. Amstrad is also said to have a new PC-compatible system in the style of the dear old PCW on the stocks.

Talking of disk drives, Apple has gone along with market pressure at last and made a 1.44Mbyte floppy standard equipment in the Macintosh SE. Existing users can upgrade their machines for the sum of £425 for all the necessary bits. The move will allow Mac users to read from or write to double density MS-DOS or OS/2 disks as well.

Martin Banks

New offshore regulations after Piper

The Department of Energy proposes new regulations for communication systems, following the Piper Alpha disaster.

DEn want VHF radios to be fitted as standard to survival craft. At the moment there is a choice between two way 2182 kHz or VHF channel 16, totally waterproof radios; but DEn feel that marine VHF radios are likely to prove more effective in an emergency.

In the future, portable VHF radios, or other devices not dependent on vulnerable power supplies, are to back-up the fixed platform public address (PA) system for emergency purposes.

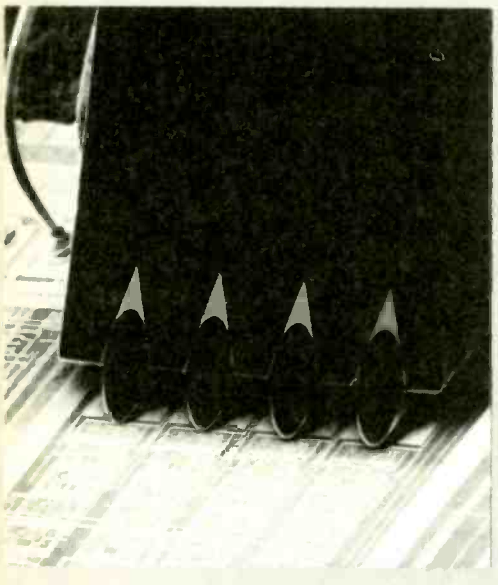
PA systems are to be supported by visual indication of platform status. DEn feels that safety would be enhanced if there were greater standardisation of alarm signals between different installations.

Lord Cullen's inquiry heard that, during the Piper disaster, there were no alarms or emergency announcements giving instructions to personnel on the installation. Survivors used their own initiative.

Integrated engineering degrees

The go-ahead has been given for six pilot schemes for a new integrated engineering degree programme in a joint initiative by the Engineering Council and the DTI.

The new courses are designed to emphasise the interdisciplinary nature of engineering; to make the career more accessible and to allow for wider choice in eventual job opportunities. Contracting universities include Durham, Southampton, Portsmouth Poly, Nottingham and Sheffield.



Gigabit optical chips

IBM researchers have demonstrated a pair of optical data transfer chips which can exchange data at 10^9 bit/s. The receiver, like the multiple laser transmitter chip, has its output fibres directly coupled to the chip surface. IBM has integrated more than 8000 transistors in the receiver, a 50-fold increase on existing opto-electronic parts. Both devices use GaAs as the substrate material.

The picture shows a portion of the receiver chip. The four large ovals are optical fibres sliced at an angle which allows the light signals to be aimed at the photo-detectors directly beneath them. The detector amplifiers occupy the space in front of the fibres.

Big bi-cmos

A 1Mbit static ram made with bi-cmos process has become a commercial reality says its creator, Toshiba. The result, it says, is a chip which can access any location in 8ns.

The combination of bipolar and cmos technology within big static rams has proved elusive until now. The complexity of the processing has always been associated with poor yields. Toshiba appears to have cracked the problem with a combination of 0.8μm geometry, very low bit line swings and a new but unspecific ECL/cmos level converter.

Mixed up asic projection

The mixed analogue/digital asic market in Europe had an estimated value of $361 million in 1988 and is expected to grow at a compound rate of 35 per cent reaching $1600 million in 1993 according to figures contained in the latest Dataquest survey.

It states that West Germany is considered to have the largest market followed by the UK and Ireland. The UK and France lead West Germany in digital asic by contrast.

ID by neural network

This work on face recognition is an extension of work already done on handwriting recognition.

The spotty area on the screen represents the link between the 'bottom' layer of 128-by-128 neurons and the next layer. It shows the weighting between the bottom neuron layer (input) and the hidden middle layer.

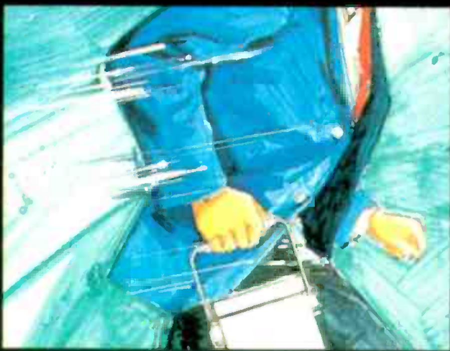
Sponsorship for the neural network aspect of the work is provided by Plessey. Martin Emerson of Southampton University has managed to get his system to recognize that the two images seen here are different.

Lowest noise op-amp

Texas Instruments claims to make the world's quietest op-amp. The TLC2201, intended for amplifying high impedance sensors and transducers, exhibits a noise current of 0.6fA/Hz with an associated noise voltage of 8nV/√Hz.

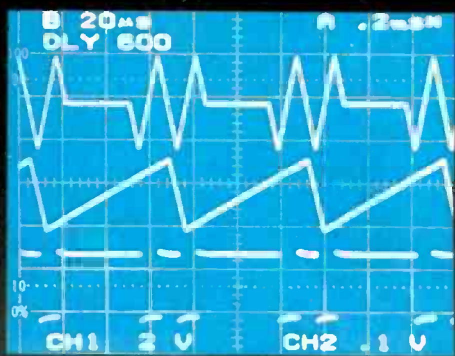
Panasonic VP-5610P

– the little 'scope that goes a long way



Mobility: Measures about 7½" × 4" × 14" and weighs in at only 11 lb. Operates from line voltages in range 90 to 250V a.c. without switching. Optional d.c. operation from 11 to 28V.

Autoranging: Eliminates need for resetting sweep range and sensitivity for each measurement. Quick and easy to use in the field.



Digital display: Main parameters displayed on CRT.

The VP-5610P gives you many of the most valued features of a bench 'scope. With three independent channels and six traces, microprocessor control, digital readout, a.c. or d.c. operation and optional GP-IB interface it goes a long way to meeting your most exciting lab. needs and is perfect for trouble shooting out in the field. It handles dual X-Y operations and offers solid state switching that's virtually impervious to moisture and contact noise. It's competitively priced too.

Just how many features can you pack into a 100MHz scope of this size? To help you find out we would be happy to send you a six page colour leaflet or arrange a demonstration without obligation.

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LIGHT IN THE SKY

Georgia Tech's high powered lasers are finding use in optical radar to reveal secrets of the upper atmosphere. Georgia Tech's James Kloepel reports.

A pencil beam of green laser light shoots skyward from an open hatch in the roof of a research building. It races through the troposphere, five, ten miles. The beam slips past piled cumulonimbus storm clouds and surges upwards into the stratosphere. Fifteen, twenty miles through the bone chilling thin air. Thirty, forty, fifty miles. The beam grows fainter but continues its upwards flight, punching through levels of the Earth's atmosphere like a bullet slicing through the layers of an onion.

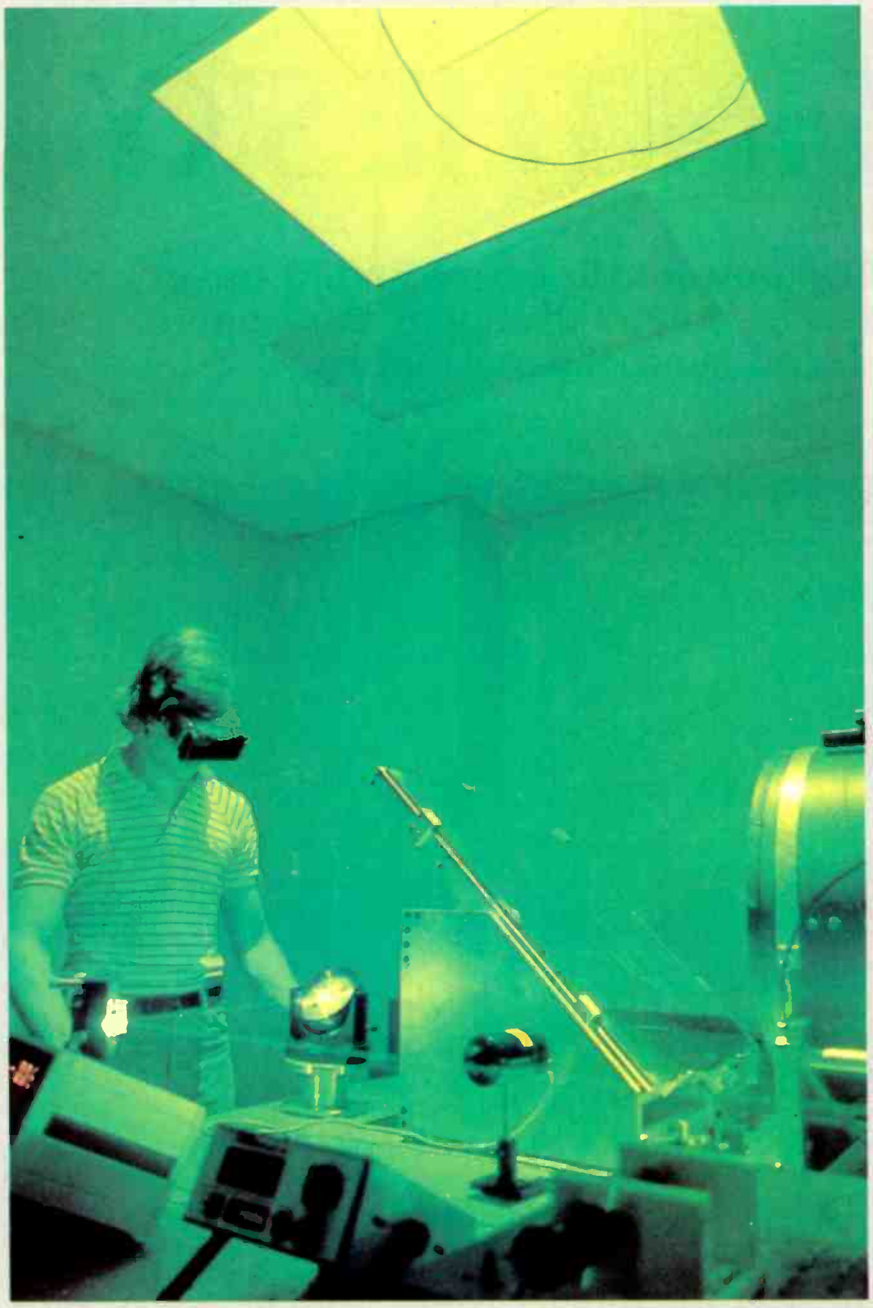
As the light beam courses through the atmosphere, some of the photons bounce off air molecules, water vapour, and specks of dust. Plunging back to Earth, these photons are collected and analysed, for now they hold important clues about the composition and behaviour of Earth's upper atmosphere.

The laser beam is part of a light detection and ranging (lidar) experiment being conducted at the Georgia Institute of Technology in Atlanta, Georgia. Like radar, lidars operate by emitting a signal and recording the resulting backscatter. Unlike radar, lidars use an intense pulse of laser light instead of radio waves.

Much more economical and reliable than sounding rockets or weather balloons – the traditional tools for studying the atmosphere – lidars can measure wind velocities, detect tenuous dust layers, determine cloud characteristics, and collect the climatological data necessary for generating more accurate weather forecasts.

Portable lidar

When lidars were first pointed at the sky back in the early 1960s, Georgia Tech researcher Gerry Grams was a graduate student at the Massachusetts Institute of Technology in Cambridge, Massachusetts. Recognizing the vast poten-



The powerful lasers used in lidar can blind instantly at many miles. Extraordinary precautions have to be taken to ensure that nothing gets into the beam.

tial offered by this unique measurement tool, Grams started using lidar to study stratospheric aerosols for his doctoral thesis.

"In those days, we used a ruby laser as the light source," says Grams. "The laser required enormous amounts of energy to operate, terribly inefficient when compared to modern lasers. The power supply, filled with banks of huge capacitors, was as large as two men and weighed nearly 400 pounds."

Not only was the laser inefficient and cumbersome to operate, but data acquisition and analysis were also tedious and time-consuming. Because minicomputers had not yet been developed, Grams was forced to record and interpret his data by hand.

Advances in computer technology and laser instrumentation over the last 25 years has enabled development of a portable, computer-controlled lidar system, a joint project with the University of Washington in Seattle, Washington. The ruby laser and massive power supply belong to a previous era. In their place is a much smaller but more efficient frequency-doubled YAG laser. Data is now collected, analysed, and displayed by a menu-driven minicomputer automatically.

EYE SAFE LASERS

In the hands of a skilled ophthalmologist, low-power lasers can repair damaged vision, but the powerful lasers commonly employed in lidars can blind – up to many miles away. Scientists and technicians working near the laser must wear safety glasses, for slivers of the beam might scatter off the optics and ricochet dangerously about the room.

For lidars, this means that extraordinary precautions must be taken to keep people out of the laser beam. The main danger is to pilots and passengers on aircraft. Most lidars incorporate bore-sighted radars as well as rooftop spotters, who constantly scan the sky and shut the system down when an approaching aircraft is sighted.

But in many circumstances, such a lidar is impractical: the military test environment with aircraft and personnel at close range, constantly moving about or an autonomous lidar, continuously monitoring cloud ceiling at an airport. Lidar requires a guarantee that nothing will ever enter the beam. Either that or the development of an eye-safe lidar with good sensitivity.

To be eye-safe, a lidar must avoid wavelengths where the lens of the human eye can focus light onto the retina, for it is this concentration of the light which causes damage. This means going to either shorter wavelengths (ultraviolet) or longer (infrared).

Georgia Tech researchers Ed Patterson and colleagues Gary Gimmestad and Dave Roberts have been developing such a system.

At the heart of the team's recently completed prototype is a methane-filled gas cell. Through an effect known as stimulated Raman scattering, the laser output is shifted to a longer wavelength. Photons in the laser beam bounce off the methane molecules, losing a small amount of their energy. The lower energy means lower frequency and therefore a longer wavelength.

The methane cell shifts the basic neodymium-YAG laser (whose output at 1.06 μm would be extremely dangerous to the eye) to 1.54μm – totally eye-safe. "Other gases with different 'Raman Scattering' effects could be used to make the laser safe," says Patterson, "but the beam must also fall within one of the atmosphere's transparent 'windows' or it would be uselessly absorbed. Methane meets both critiera."

It is a fortunate coincidence that 1.54μm also turns out to be the wavelength of choice for transmitting over long distances using fibre optics. The special optics and detector Tech's system required were conveniently found within industry. This novel lidar has been field-tested and proven eye-safe. "You could stare directly into the beam and not hurt your eyes," says Patterson.

"The system is very easy to set up and use," says Grams. "In a truck-mounted configuration, the lidar can be operational within an hour or two of arrival at a remote observing site."

Mysterious arctic haze layer

Grams recently modified the portable lidar system for operation in an aircraft. He and his colleagues will use the instrument to investigate the height and concentration of a mysterious arctic haze layer that forms each year during the arctic spring.

Not only is the composition of the layer currently unknown, its origin also remains a mystery: the individual dust particles may have drifted for thousands of miles before becoming trapped in the arctic sky. To learn more, the US National Oceanographic and Atmospheric Administration (NOAA) initiated the Arctic Gas and Aerosol Sampling Program. Participating scientists will explore the height, thickness, and chemical composition of the mysterious layer.

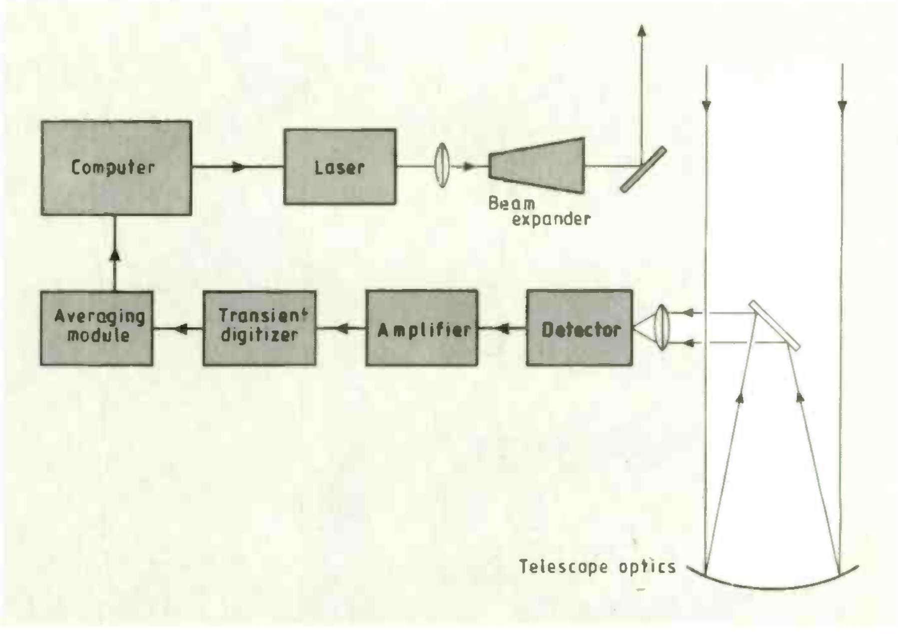
The group expects lidar to detect the exact location of the haze layer, which is not discernible with the naked eye. The system can look up or down to identify the middle of the dust layer and inform the pilot where best to fly. Other onboard instrumentation, including gas and particle samplers, will then be used to identify chemically the material forming the layer and determine its concentration and other physical characteristics.

Monitoring subvisual cirrus

Used on the ground, the portable lidar can monitor the presence of subvisual cirrus. Invisible to the eye, these clouds trap infrared radiation, making a significant contribution to the greenhouse effect with its attendant effect on the Earth's climate.

"Some researchers believe there may be enough subvisual cirrus floating around that the long-term radiation balance of the Earth cannot be properly calculated," says Grams. "We need to determine the extent of these clouds on a global scale, and what cumulative effect they have on the earth's radiation balance."

Subvisual cirrus can also seriously affect the performance of infrared sensors used to detect approaching missiles or hostile aircraft. "Although the clouds usually form a layer only a few hundred feet thick, they often extend laterally for many miles. These clouds absorb infrared radiation so effectively in the horizontal direction, a pilot relying on his sensors might not detect a threat until it is too late. And because the clouds are invisible from above or below, a pilot never knows when he might be approaching such a layer" says Gerry Grams.



Typical lidar block diagram. Aircraft mounted versions extend the scope of upper atmosphere research. NASA plans a satellite mounted Doppler lidar for wind speed measurement.

To generate necessary guidelines for pilots, models must be developed that accurately predict the conditions in which troublesome clouds form. Lidar systems could prove valuable in exploring these and other important models.

For example, last summer while Grams and graduate student Eric Schmidt were taking measurements of subvisual cirrus over Wright Patterson Air Force Base in Dayton, Ohio, Yellowstone National Park was a raging inferno. Trace after trace of the researchers' data showed not only the sought-after clouds, but also distinct layers of high-altitude smoke drifting from the distant fires.

They expect the wealth of smoke data to test and validate existing models concerning the long-range transport of particles. In addition to the obvious climatological applications, such models are also used to predict how fallout from nuclear tests or accidents may be dispersed around the globe. The importance of such models is self evident.

Improved weather forecasting

Meteorologists can predict the weather for up to five days with reasonable accuracy. To generate long-range forecasts, however, much more data on global wind profiles is needed.

"Because much of the Earth's surface is covered by oceans, such data is not always available," says Ed Patterson, a senior research scientist at Georgia Tech. "Except for a few islands and scattered ships, we receive very little input on the direction or force of winds blowing over the oceans."

To fill this gap, the US National Aeronautics and Space Administration (NASA) envisages the placing of a powerful Doppler lidar in orbit by the mid 1990s. Called the Laser Atmospheric Wind Sounder (LAWS), the satellite will probe Earth's atmosphere, measuring global wind profiles from the ground up. While technology exists to build and orbit the sounder, certain criteria still need to be established.

"Like ground-based lidars, LAWS will operate by measuring aerosol backscatter," says Patterson. "Since much of the LAWS data will be taken over remote regions that are generally free of smog and other aerosols, there is some concern over how much backscatter the instrument is likely to see."

Given information on existing lidar capabilities and anticipated levels of backscatter, NASA will determine appropriate LAWS design parameters. More accurate long-range weather forecasts may be a satellite-launch away.

Lidars generally appear to be faster, cheaper, and more dependable than sounding rockets or weather balloons. ■

Better devices for power rail monitoring

With increasing interaction between microcomputers and analogue systems, the power supplies of both must be monitored to prevent the possibility of erroneous data being processed by the microcomputer.

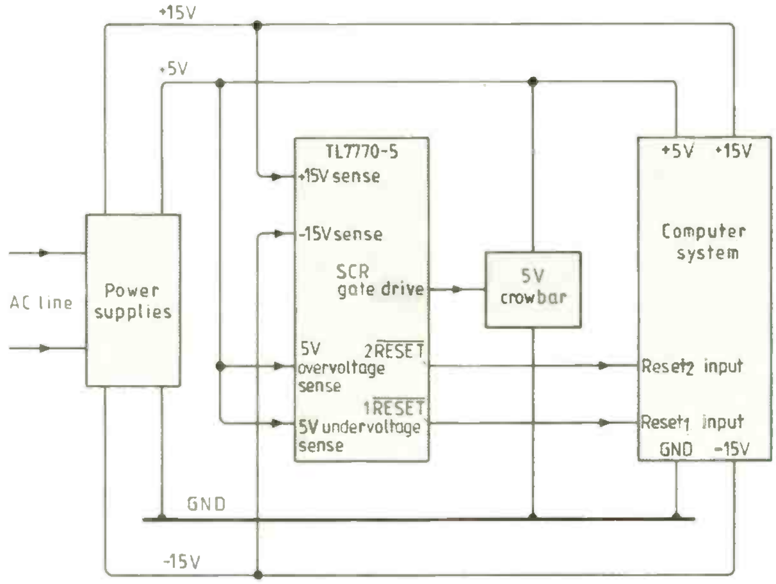
About five years ago, Texas Instruments introduced two devices to monitor the standard digital and analogue voltage rails. These were the TL7705A, a digital 5V monitor, and the TL7702A positive and negative analogue rail monitor. They soon became virtually standard parts in the hardware designer's tool-kit to monitor power supply integrity and act to protect the microprocessor or computer and memory if power supply problems were detected.

The TL7705A has a preset threshold on the sense input, enabling it to monitor 5V supplies directly and provide voltage power-up and drop-out system resets for a microprocessor or computer. The TL7702A is able to sense either the positive or negative analogue rails, but two are required together with a TL7705A to provide full power supply monitoring for a mixed microcomputer and analogue system.

Many of today's developments in electronics involve creating a single device to do the job previously done by two or more. In keeping with this trend, Texas Instruments has recently introduced a new device, the TL7770-05, which does all that can be done with one TL7705A and two TL7702A. In addition it provides dual over-voltage sensing and dual SCR gate drives for crowbar protection. Furthermore, the chip's defined state of operations begins at just 1V, and so it can provide an early system reset signal during power-up!

Fig. 1 shows the block diagram of a typical microprocessor application using a TL7770-05, providing both over and under-voltage protection on the 5V primary supply and undervoltage protection on the ±15V peripheral supplies. This device certainly simplifies the hardware design in a monitored power supply and its additional features will enhance the protection offered. The cost of the part is about £0.92 per piece for 100-up quantities, which is very good value for money considering it is replacing several devices and offering more features.

Fig. 1. Multiple power rail monitor based on Texas Instruments' TL7770-05.



Big is essential

Plant costs for semiconductor manufacture are becoming increasingly more expensive as the technology advances, with typical replacement cost estimates being in the region of £100M. To remain competitive, major semiconductor manufacturers must renew their process plant approximately every five years to keep up with technological developments. Rather like the changes we saw in the motor industry some ten years ago, it seems that with such high capital costs, only companies with sufficiently high business turnover will survive; that is, big appears to be essential.

One recent example of the consolidation that is going on in the semiconductor industry is the expansion of Harris Semiconductor, one of four major sectors within the Harris Corporation, through the acquisition of GE Semiconductor, RCA Solid State and Intersil. The new, much bigger, Harris Semiconductor claims to unite and strengthen four broad-based semiconductor suppliers and intends to market products under the brand names of Harris, RCA, GE and Intersil. The company also claims to be the sixth largest US merchant producer of semiconductors, with one of the broadest and most varied product lines.

Current-sensing transistors

Among the stable of products now under the umbrella of Harris Semiconductors are the relatively new current-sensing insulated-gate power BJTs (IGBTs) developed by GE Semiconductor. The device is essentially a mos-gated power-switching device combining the best features of power mosfets and power BJTs, with integral current-sensing.

It displays the extremely high input impedance typical of a mosfet, with low on-state conduction losses typical of a bipolar junction transistor. In performance, the device appears to be like a power mosfet, except for the on-resistance, which is about 10 times lower. Unlike the conventional power mosfet, its on-resistance varies very little over the usable temperature range.

Three current-sensing IGBTs are offered by Harris, types GS1510, GS1525 and GS1550. They have been designed for high-voltage switching applications up to 5kHz where low conduction losses are essential, as in AC and DC motor controllers, power supplies and drivers for solenoids, relays and contactors. All three devices can switch loads of up to 500V, the maximum current handling being the last two digits on the part number; ie the GS1550 is a 50A, 500V device. Costs are around £2.78, £8.10 and £28 per

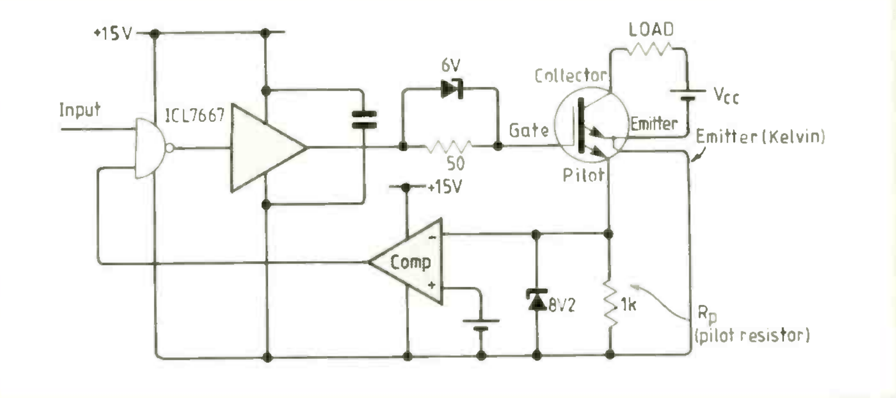


Fig. 2. Using a pilot resistor for overcurrent protection.

piece for the GS1510, GS1525 and GS1550 respectively.

Fig. 2 shows a typical IGBT switching circuit with over-current protection. A scaled-down copy of the collector current flows out of the P terminal. With a resistor inserted between the P and EK terminals the V_{PEK} voltage is proportional to the collector/load current and may be used to provide current limiting.

Further developments from Harris Semiconductor likely to result in useful power devices in the not too distant future are mos-controlled thyristors (MCT), which will behave like thyristors that can be turned both on and off with a mosfet type of input impedance; and power mosfets which can be turned on with 5V input signal levels, rather than the higher values that are needed for today's mosfets (typically 8V).

Analogue at ECCTD '89

The European Conference on Circuit Theory and Design (ECCTD) for 1989 was held at the University of Sussex from September 5-8. Over 140 papers were presented, written by some 295 international researchers. The IEE which organized the conference, has published the papers in a single soft-cover book (IEE conference publication number 308, ISBN 0 85296383 1).

Most of the papers are non-analogue in content but several of the others caught my eye, and here I give you a thumbnail sketch of some of them.

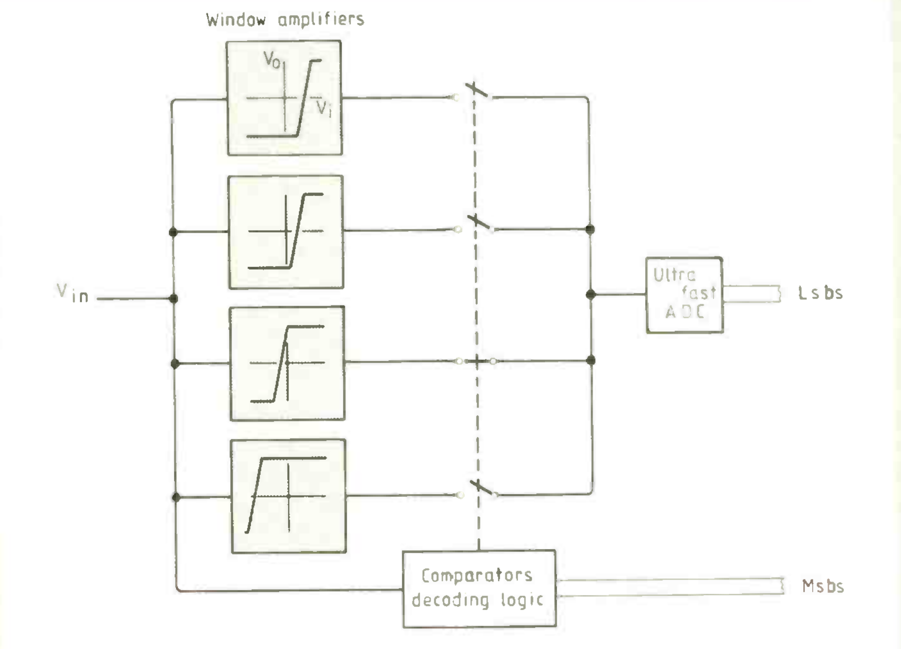
Identification of small-transistor models (Vidkjaer, pp99-103). This paper deals with the difficult area of trying to identify an apropriate small-signal model for a particular transistor and how to extract small-signal parameters from measurements intended primarily for high-frequency applications. The author outlines a systematic procedure which is intended to keep the effort to an acceptable level. All the expepimental work is based on S-parameter measurements.

This paper is not for the timid high-frequency analogue designer. However, a useful technique for identification of small-signal transistor models is presented with test examples.

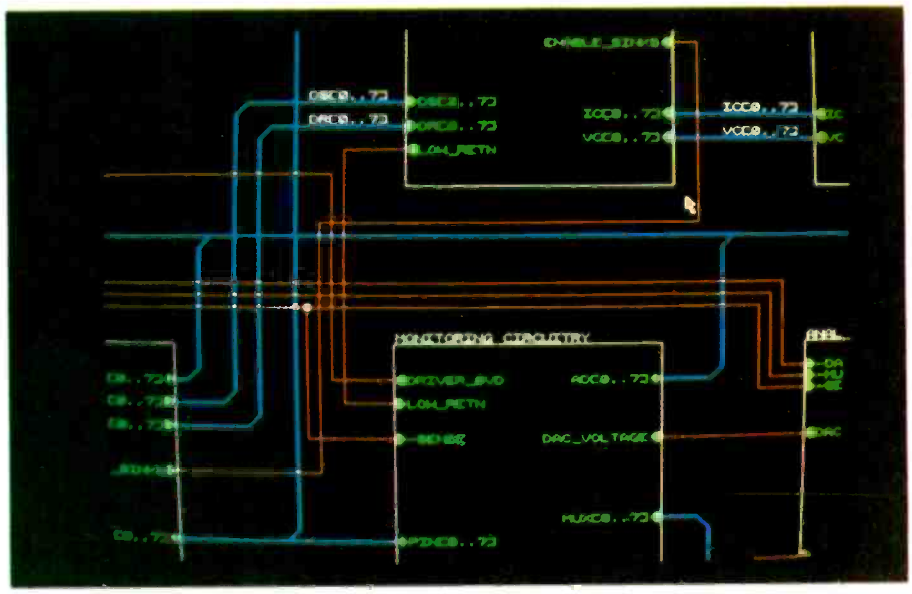
A novel, fast, high-resolution ADC-structure (F. Viehbock, H. Furst, pp214-217). The fastest way of converting an analogue signal into digital form is with a string of comparators, each set up with an input reference voltage differing by a voltage equivalent to one LSB from its nearest neighbour. This is called a flash converter, for obvious reasons, and the conversion time is controlled mainly by the switching time of just one comparator. The problem with the flash converter is that it requires so many comparators: for n-bits the number needed is 2^n-1.

The A-to-D converter presented in this paper is not as fast as a full flash converter, but it uses many fewer components and the performance, it is claimed, rivals other converter architectures in terms of speed and complexity. **Figure 4** shows the basic block structure of the new converter. The analogue input is fed to a set of window amplifiers, each amplifying only a dedicated portion of the input range. Only one of the window amplifiers will be activated by the input, and the output of that amplifier is then fed to a flash converter. The window amplifier is designed so that the output will be zero if the input voltage is just in the bottom of a particular window, and equal to the full-house reference voltage if at the top.

Using four window amplifiers, together with an eight-bit flash converter, ten bits are achieved. To make an eight-bit flash converter into a 10-bit flash converter would require an additional 768 comparators (2^{10}-2^8). The authors openly discuss some of the problems with the architecture and propose improvements. It will be interesting to see whether any new converters based on this architecture appear from the semiconductor manufacturers in the next year or so.



Drawing with Orcad SDT



Putting a computer behind the drawing board allows the designer to work faster and with less chance of silly errors. Brian Frost puts this popular cad package to the test.

Orcad SDT is one of the newer generation of circuit-drawing programs that position themselves between simple drawing packages that manipulate lines and geometrical shapes and the fully integrated suites of software found in workstations. It does not provide new feaures, but it does provide well-behaved design assistance at a fraction of the cost of a workstation. There is now a huge library of component shapes in existence.

Schematic capture uses the computer to ease the repetitive tasks, leaving you to make the appropriate connections between the component parts that you have chosen. These parts are held within a component library, from which they are fetched by name to the screen, complete with their correct pin numbers and signal names. This immediately avoids the common mistake of making pin-numbering errors when copying a logic part from data book to circuit diagram.

With this component on the screen, it can be dragged around, fixed where desired, have wires added to it or be rotated. Circuit modifications are therefore quickly made and can be printed as many times as required in various drawing sizes.

As an example of this process, consider the diagram shown in **Fig. 1.** This was created using Orcad SDT and shows a simple crystal oscillator. Out of interest, I timed how long it took me to draw this identical circuit on paper using a ruler but no drawing ink or text stencils. Using this 'conventional' technique it took me 6min 30s to complete the drawing, including the unused logic pins. I then entered it on the computer, taking 1min 30s. Both tasks include the time involved in consulting the data book for information.

As well as the time saving, there is much more flexibility in the computer-based version; before adding more circuitry, the circuit block shown can be dragged across the screen to create the space required in a few seconds. More time-saving is obtained by allowing the computer automatically to annotate the circuit with component reference numbers. This takes only a few seconds and replaces a laborious manual operation and limits errors.

Hardware requirements

Although the resolution of the CGA standard is adequate for representing circuitry on screen, text such as pin numbering is poorly represented, with obvious gaps between the 200 horizontal lines. VGA shows little granularity on sloping lines. Alternatively, EGA shows only slight granularity.

The most basic PC-XT is quite capable of performing all of the tasks listed here. The PC-AT shows a speed improvement of some 4-6 times in the calculation of netlists, with the newer 80386 machines calculating up to 10 times faster.

The appearance of the finished diagram will depend upon choice of printer or plotter. The low cost of 24-pin dot-matrix printers offer an acceptable compromise. Laser printed output provides quality consistent with photography.

Increasing productivity

One of the greatest increases in productivity comes from the fact that most designers have favourite circuit configurations which have been optimized by experience. Designing in this modular way allows such function blocks to be fetched from previously drawn circuitry and placed into the present design without any modifications other than the reconnection of the interfacing signals and power supplies. Even the re-annotation of the old components is automatic.

Of course, real circuit diagrams are much more complex than that of Fig. 1 and are usually too large to fit in the space shown. This is a common objection raised against cad: that a hand-drawn circuit on (say) an A0 sheet can show all the signal flow and circuit simultaneously, whereas smaller prints cannot. Although this appears to be a drawback, it is not a limitation of the computer, since the drawing 'sheet' is usually larger than the screen display, and can be theoretically limitless.

The limitation – if one exists – is that of transferring such a large sheet to paper where only a suitably sized plotter can produce large single sheets. Alternatively, a large diagram is split up into a number of smaller (e.g. A4) size sheets, with the appropriate signals interconnecting them. Partitioned with a bit of planning, this method provides room to add extra circuitry with ease and permits the easy export of such circuit modules on to future drawings that require similar circuitry. A4-sized sheets are ideal for manuals.

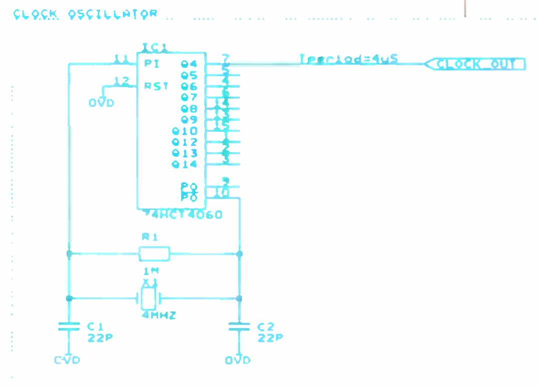
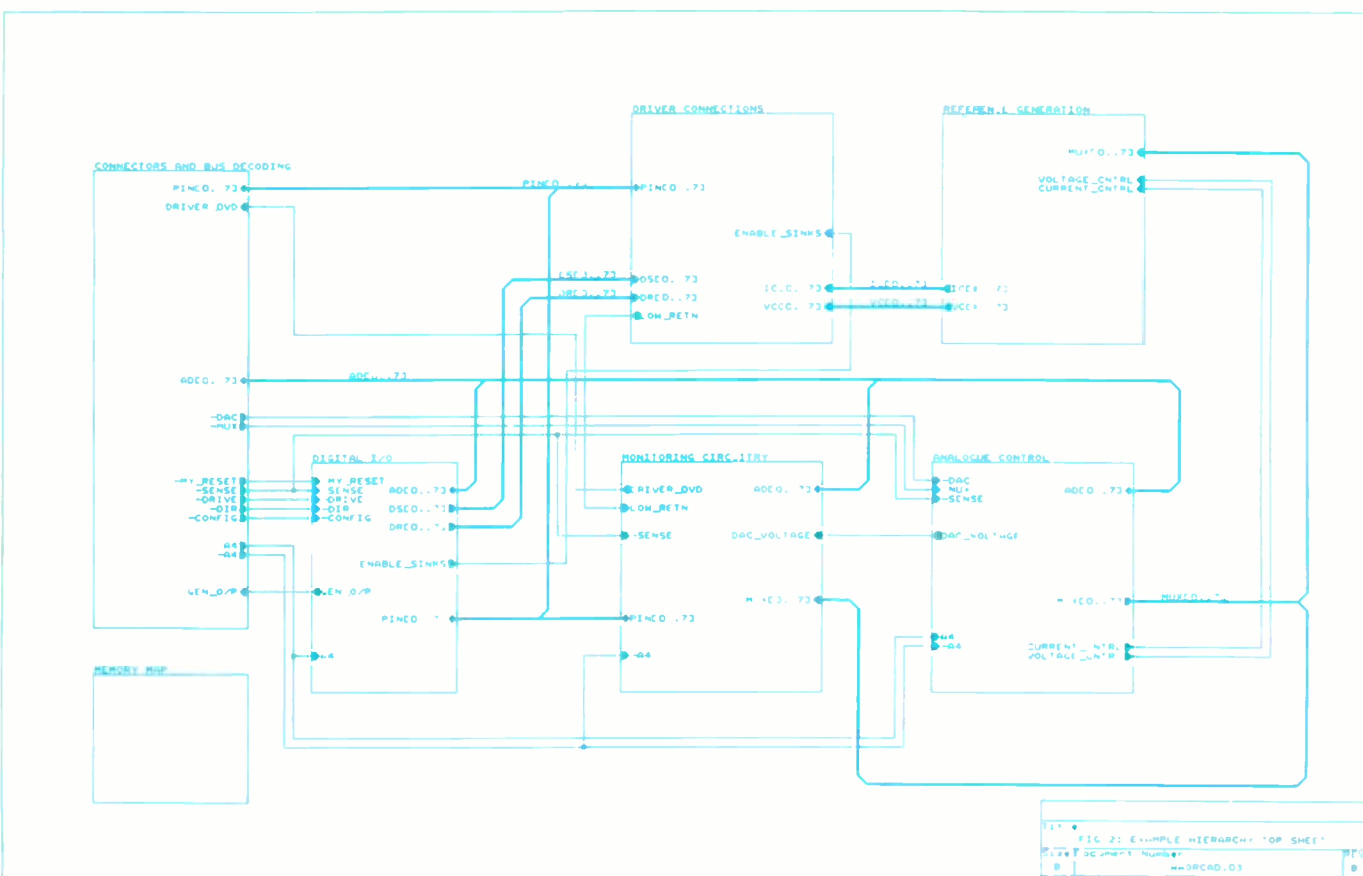


Fig. 1 Orcad's time savings are well illustrated with this simple crystal oscillator, which took 6½min to draw by hand with a ruler, and 1½min using Orcad.

Fig. 2. Massive drawings are handled by partitioning in Orcad. This top-level screen shows multiple sheets connected together in a similar way to components with signals pasing to and from that sheet being analogous to pins.



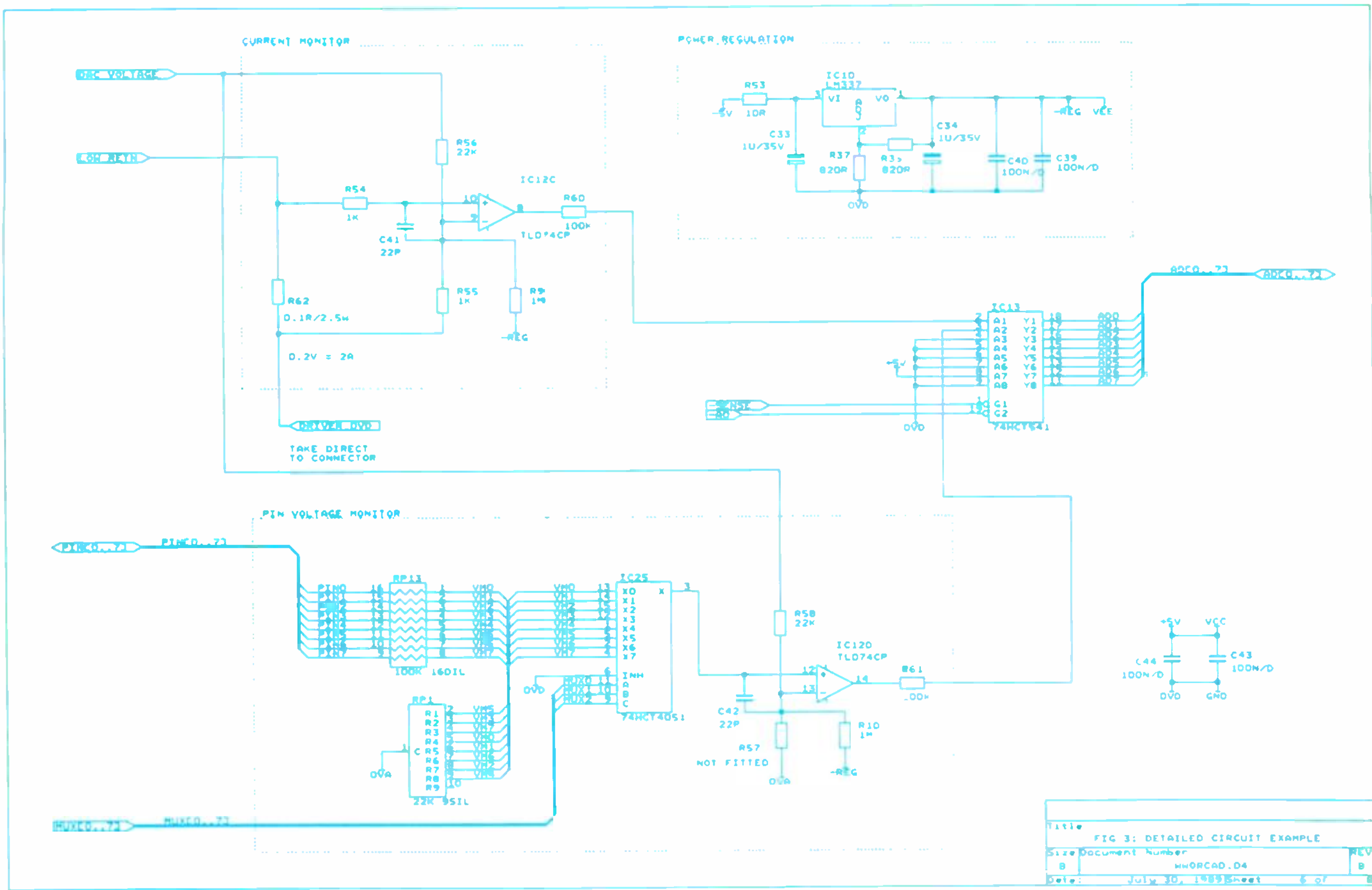


Fig.3. Actual circuitry for the 'connectors and bus decoding' panel, for example, in Fig.2 are detailed separately to avoid cluttering the main worksheet.

Once the circuit is drawn, the computer can start work. With one simple command, the entire circuit diagram of many sheets can be annotated with ascending component references with no intervention from you at all. With another simple command, a complete parts list is generated from these references, which shows all parts, their references and names. Another command produces a 'wiring list', or netlist, which describes every part on the diagram, with all its connections to other parts. This information can be accepted in a variety of PCB layout systems, so that connected components can be positioned where required and connections on the final PCB will follow the original circuit.

The drawn circuit may be simulated – a technique particularly valuable for logic circuitry[1]. This involves creating a hypothetical stimulus-signal file for the circuit's inputs and then running the simulation to provide the computer's prediction of the resulting output or component node signals. This can be done before or during the existence of a wired prototype.

Running the drawing program (DRAFT) puts you into graphics mode within its graphics editor. A mouse or cursor keys moves a graphics pointer around the screen and selected keyboard character keys initiate drawing actions; pressing the return key brings up a menu showing the options. The program can be menu-driven with the mouse selecting from this menu, but faster operation can be obtained by typing the first letter of the operation on the keyboard. For example, the string PWB instructs the system to "PLACE WIRE BEGIN," and the start of a wire appears at the cursor.

This wire stays with the cursor you as you move it vertically or horizontally; if you move diagonally, a 90-degree corner is inserted. At any time, a click of the left mouse button freezes the last corner, allowing you to route a wire across a sheet, through available gaps, with no further commands. The last mouse click or a press on the E (for end) key terminates the wire at the current position.

The Orcad SDT screen is really a 'window' in the worksheet on which you are drawing, with this limitation made acceptable by an auto-scrolling action which causes the screen to follow the cursor across the drawing if it reaches any of the screen boundaries. It is unnecessary to use separate keys to move around the sheet, as is the case with many competing schematic capture packages. At any time, you can zoom in or out at will to see more detail or more diagram. As you zoom out, text detail is progressively lost, allowing you to identify part shapes and position the cursor. As you zoom in, the maximum possible detail and text that the graphics hardware allows are written at each zoom level.

To fetch any component, you type G (for get) together with the name of the component in the library; on hitting 'return' instead of the component name, a list of library filenames appears in a menu. Some 10-12 files are supplied with the package, covering over 1000 total library parts. Using the mouse, it is easy to scroll through the available library parts.

Having fetched a part, only its outline appears on the screen at the cursor position and without any text such as pin numbers or names; this shell moves with the cursor until the use of P (for place) drops it. This causes the component to be fixed at that position and to be drawn with full pin and text details on the screen. The component outline remains at the cursor, to allow copies of it to be dropped where required with repeated P commands.

Parts are shown in their usual electrical symbols with many parts offered in a choice of styles, for example the American and European styles for an electrolytic capacitor. Most parts have only one function in their package, and these are drawn as simple rectangles with pin numbers and names around the edge. Parts that have several identical functions within the same package, such as a 7400 quad nand gate, are drawn using the conventional nand-gate symbol, and pin numbers are those of the first device of the four within the package, i.e. inputs on 1,2 output on 3. This allows the four gates in one package to be used anywhere and to be shown as conventional logic symbols without having to draw wires back to one dil device package each time a gate is used.

Many gates can be displayed using their DeMorgan equivalent, for example an or gate with inverting inputs instead of a nand gate. The general convention is that logic parts do not show their power pins; these are automatically connected together without needing to be wired further, to enhance the readability of the circuit.

With parts placed on the sheet, they are now electrically connected together using either wires or buses. A bus is shown as a wide wire, which expands into one or more of its component wires anywhere along its route. Buses are good value in logic diagrams, particularly in memory and processor circuitry, since they may be manipulated just like a wire despite representing hundreds of connections.

For annotating the wires at the ends of buses, a repeat facility allows the last text or label to be repeated with a defined position and numeric increment. For example, placing the label A0 as the first connection of an address bus allows you to press R repeatedly thereafter, generating a new label advanced by one number and stepping downwards on the screen to create the list A0,A1,A2,A3 . . . etc.

Block commands allow everything within a defined boxed area to be either deleted, moved or dragged to allow parts of the diagram to be entered within available space or to create space for additional circuitry. This is so fast that the drawing can be tidied as you go, so that connections do not have to be redrawn later. Parts may also be repositioned, rotated or mirrored.

While each sheet is a disk file in its own right, a block of circuitry within one sheet may be written to a file to be subsequently read back into another drawing. This allows the user to generate a new diagram either by building it 'from the ground up' using individual components out of the library or by using blocks of circuitry already in existence.

The user can select the size of worksheet for the diagram by selecting the American designation A,B,C,D, in theory allowing as much space as is necessary for the required components. While the software is quite capable of handling very large drawings, the problem comes during printing where, unless you have a large plotter, you cannot print your single sheet (although a large drawing can be broken into a number of sheets to be fixed together). A convenient solution is to break your drawing up into circuit modules and use the capability of Orcad to handle a hierarchy of diagrams.

The top sheet of such a hierarchy is shown in **Fig. 2.** This shows how the separate drawing sheets can be placed within another sheet and shown as a component with connection names that represent the signals passing to and from that sheet, as with component pins. At the top left you will see a box labelled 'Connectors and bus decoding'. The circuitry for this sheet is shown in **Fig. 3** but on this top sheet, only the signals that enter or leave it are shown. The hierarchy system can also be used to create additional information about a diagram, for example a timing diagram can be appended to a logic circuit by using a sheet box named TIMINGDIAGRAM.

Since Orcad SDT expands any one circuit sheet to include other sheets referenced within it, all of its utility operations operate on the entire drawing, irrespective of the number of sheets involved. The result is that working on a 25-sheet drawing is little different from working with only one sheet.

Since circuit drawing and modifications can involve significant repetition, the software implements a text MACRO capability. Because all recorded cursor movements are made relative, this allows a manual editing operation on the first of several parts, ending it with the cursor ready at the same starting point on the next part to edit.

Producing results

Having created your circuit diagram, copies can be printed or plotted and a number of utilities is supplied to support the circuit diagram and attendant documentation. The ANNOTATE utility will move throughout all the sheets that make up your diagram and add component references in ascending order. There is one disadvantage with this: if you add a couple of new components to the drawing after having annotated it, there seems to be no way of using ANNOTATE again to add these as sequential component references without the risk of changing the existing numbering.

Producing a parts list is easy. The PARTLIST utility scans the drawing sheets and produces a list of each component type, with quantity used, name and reference. A cross-reference program CROSSREF produces a list of components against sheets and their inverse. This is useful for locating a component within a drawing of many sheets because, although there is a find command to search for text whilst editing, it only operates within one worksheet and cannot operate globally.

The utility NETLIST is used to produce a list of parts and interconnection data that can be imported into other cad systems prior to PCB layout. This also checks all the interconnections on your diagram, issuing warnings about such things as unconnected wires, buses or components.

A utility called ERC – electrical rules check – uses information about each pin of a part to verify that connections to it conform to the electrical conditions allowed for that pin. For example, two pins connected together, where both of these pins are defined as output pins within the library data, would generate a warning message when running ERC. Note though, that if you choose to ignore these warnings, Orcad assumes that you have a good reason.

Component library

Orcad SDT has an extensive library and, in the latest releases, has a library parts editor LIBEDIT that can quickly create new parts instead of using the original, slower, text-based process.

All components are held in library files in a compiled format that enables fast retrieval but with utilities supplied which allow translation to and from ordinary ascii text files. For example a cmos 4060 device is contained within the library file CMOS.LIB.

Reference

1. Frost, Brian DIY PLD. *Electronics and Wireless World, May, 1989.*

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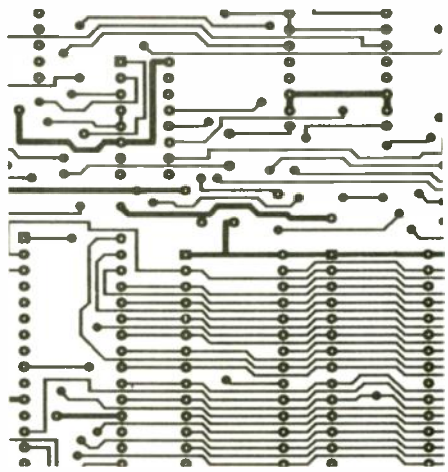

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14 2764/50ms	37 uPD27C1000D	60 2817A	83 8048*	
15 2764	38 TC571001D	61 2864A	84 8049*	
16 2764A	39 HN27C1024G	62 EMULATOR 2716	85 8050*	
17 2764A/QP	40 NMC27C1024	63 EMULATOR 2732	86 8751	
18 27128	41 uPD27C1024D	64 EMULATOR 2764	87 8752	
19 27128A	42 i27210	65 EMULATOR 27128	88 87C51	
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CIRCLE NO. 104 ON REPLY CARD

Who's who in risc

The technical and business desktop computer world is ready to believe in Unix V rather than OS/2. The chip makers are lined up on the starting grid, Unix risc engines revving. By Rupert Baines.

Conventional wisdom has it that there's only room for two processor families in the market-place. When manufacturers launched the first 16-bit devices only Intel's 8086 and Motorola's 68000 made it to security and volume sales. The rival processors from Zilog, Texas Instruments, Fairchild and National Semiconductor all lost out, and those companies have never managed to re-enter that market. It's possible that the risc marketplace will be less bloodthirsty, but it's unlikely – and none of the manufacturers are prepared to risk being the ones left behind. As a result, all of them are spending fortunes on advertising to convince people that theirs is the best device available (the fastest, the cheapest, the most useful or whatever). Of course, there's no infallible way of predicting the future, but it is possible to make some guesses about the state of the market to come.

Both Intel and Motorola are big enough and rich enough to win through: Intel's 80860 is also a staggeringly good device that's incredibly faster than anything else around. The built-in graphics support has helped it gain its first design win in a flight simulator application – the combination of fast number-crunching and built-in graphics makes this an obvious choice for any application involving animation or pictures.

Motorola have the marketing clout to make sure that their 88000 product succeeds. It doesn't have an obvious niche to grab, unlike the 80860, so it will be fighting it out with the rest of the devices in the processing mainstream with the rest.

The R3000 and the sparc are interesting because they are 'open architecture' devices (see panel) and are being manufactured by a number of sources.

ADVANTAGES OF AN OPEN MIND

The sparc and R3000 risc processors are intriguingly different from the other devices. The companies that designed them – MIPS and SUN respectively – are not chip manufacturers: instead they've allowed a number of different companies to produce and sell the chips under licence. They are planning on making their money from the royalty feeds and spin-off business (for instance, associated compilers) rather than from the chips themselves.

These open-architecture chips are being produced by different manufactures, each of which are able to exploit their particular specializations to enhance the design. For example, the sparc processor is available in forms, ranging from the low-power c-mos offerings of LSI Logic and Fujitsu to the very fast, very power-hungry ecl model made by Bipolar Integrated Technology.

There is also a much more interesting benefit: since the manufacturer has the net-list of the device it can easily be modified or customized. Essentially, customers can therefore treat risc chips as the basis for their own personalized processor design.

A company like LSI Logic may be heralding a new trend by offering customers the opportunity of starting with a sparc processor and customizing it. The original design could be then modified or altered to suit the particular specifications of an application. Alternatively, the entire processor could be used as the core of an asic design, with extra logic, memory and specialist digital or analogue I/O all included in the same piece of silicon. This is an incredibly flexible approach that adds a new meaning to the phrase 'single-chip solution'. (Intriguingly LSI are the only company who are licensed to produce both of the MIPS R3000 and the sparc processors).

The other large semiconductor manufacturer in the risc game is AMD with their 29000. This is definitely targetting the control market, with its fast response times and task-switching. It wouldn't be surprising to see it cropping up on a lot of embedded real-time systems. Its first major design win has been from Apple: the chip will be used as a co-processor to speed up the QuickDraw graphics routine in the next generation of Macintosh computers.

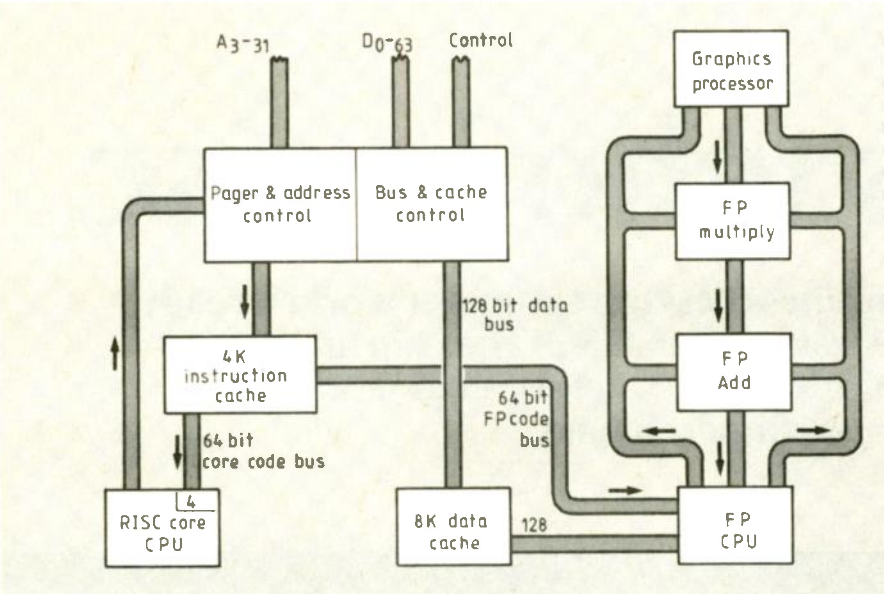
Finally, there's Acorn; the British contender in the risc wars. This was one of the first risc chips on the market and has perhaps the highest total sales volume, purely because of its use in Acorn's Archimedes home computer. This is its only known application; the chip is available though I haven't heard of any other users. The neat features of the architecture (the test op-codes) would make this chip well suited to embedded control, where a fast response is essential.

INTEL 80860

This chip, announced in March, has transformed the risc scene. Until then performances were measured in Mips and tens of Mips; a rating of 20 million instructions in a second was as impressive as it sounds. But the 80860 has smashed all previous speed ratings and blown everything else out of the water. It can turn in speeds of up to 150Mips, more than seven times as fast as its nearest competitor! Hyperbole just doesn't do justice to this processor.

The device gets its speed from brilliant design in three different areas. To start with, there's a lot of parallelism inside the chip, with a great deal of activity going on at once; secondly there are the hugely wide data buses capable of carrying four 32-bit registers and two instructions simultaneously. The on-chip bus bandwidth is more that 1Gbyte/s! Finally there is the incredible system clock frequency of 40MHz.

Risc simplifies the design of a proces-



Intel's 80860 derives its blazing speed from its wide buses, huge cache memory stores, an abundance of pipelines and a lot of concurrency.

sor. Some manufacturers have taken advantage of this to make smaller, cheaper chips that need fewer transistors and are easier to make (e.g. the ARM, with only 25 000 transistors). Intel has gone the other way with the 80860, a huge device with more than a million transistors (the same number as its new 80486 cisc device). Since the processor core has been simplified there is plenty of room for other parts that would normally be external components. For instance, there are two large cache memories which take up 40% of the silicon area. There just would be no space for them on a conventional cisc device.

Part of the reason for the processor's stupendous speed is that it runs at an extremely high clock rate: the lab sample device runs at an incredible 50MHz and the first production units stroll in at an impressive 33MHz. All risc devices aim for one instruction per clock cycle, but even without any special features the 860 would be at the front of the field purely by virtue of this. The faster the clock ticks, the more instructions can be forced through the chip. Until now 25MHz has been the maximum, the speed of the very latest chips (including the M88100 and the 80386) so the new device has already benefited from a 100% speed gain. A system clock of 50MHz allows only 20ns for each cycle, which leaves no room for the slightest skew or drift in co-ordinating the separate parts of the processor.

But the fast clock speed is only part of the story, since even a 25MHz version of the 80860 would turn in a frightening 75Mips, which is still triple the speed of a M88100 running off the same clock! The rest of the speed gain comes from the way that the chip has been designed to support a vast degree of concurrency, with many different things happening at once. There are three distinct processors that can work independently: the integer risc core processor, a powerful floating point coprocessor and (an unusual addition) a dedicated graphics processor.

The core processor has its own 64-bit-wide code bus, which means that two instructions are fetched from the internal code cache at a time. These are fed into the processor's own pipeline, which is four stages deep with hardware interlocks and delayed branch instructions to reduce the effects of bubbles. The combination of cache, pipeline and double fetch helps make things move quickly! In common with most risc devices, the 860 has a load/store architecture and so all instructions use operands held in the register files (32 registers, each 32 bits wide). The core processor also connects to the data bus which is a phenomenal 128 bits wide – enough to transfer four registers at once.

The floating point unit has three separate parts: its own processor, an adder and a multiplier. The control unit also has 32 registers, which can be treated as 32, 64 or 128 bits wide depending on the needs of the application. Both the adder and the multiplier have their own three-stage pipeline (for single or double precision operands) and they can run in parallel. The floating point processor has its own separate 64 bit instruction bus to receive its 21 unique instructions.

The quoted figure of 150Mips at 50MHz requires the processor to run three instructions per cycle. This happens with one integer and two floating point operations being executed at once so it isn't typical for most applications. For this mode to be sustained the adder will be working on data supplied by the multiplier. At one moment the multiplier generates a term for the next calculation while the adder is completing the current sum – two floating-point instructions at once. Since the core unit will be running its own code too, that gives the total of three. Obviously this rate isn't sustainable for ever; but it does allow for some very useful techniques. For example the core could be handling a loop counter while the floating unit does its operation, thus:

A = (B*C) + D, INC i in one cycle

This kind of loop is typical of the number-crunching tasks for which the device is intended (e.g. graphics calculations, FFTs, cad etc.). The 33MHz device will complete a 1024-point FFT in just 2ms, quicker than some DSP chips!

The third coprocessor on the chip is an unexpected one, a dedicated graphics controller. It's intended to help designers of workstations and so on. The chip uses 64-bit logic to handle graphics applications in 3D-like colour, with intensity shading, hidden surface removal and flood-fill – all from hardware. This unit has 10 special instructions and its own pipeline. Inevitably this too works concurrently with the other sections of the chip! It's rated at drawing and shading 50 000 triangles a second, which is probably enough for most of us.

MIPS R3000

This processor seems to suffer from an undeservedly low profile. Until Intel dropped its 80860 bombshell, it was the fastest device on the market by a clear margin. It was designed by MIPS of California, which can legitimately claim to have started the commercial risc market. Its earlier product, the R2000, was the first risc chip when it was released in 1985, and MIPS is still the only pure risc company, with no other products or interests. The R3000 is the only second generation processor thus far; it is also the only chip to have demonstrated true scalability (reducing the design from 2μm to 1.2μm to quadruple the speed).

The processor is a 32-bit device, with an on-chip memory management unit which can address 4Gbyte of main memory, a cache controller and a "seamless" interface to the R3010 floating point coprocessor. Like Motorola M88000 it has a Harvard architecture, with separate data and address buses for code and data memory spaces (i.e. four external in total). The chip has 32 registers, 30 of which are true general-purpose types. Register R0 is hard-wired to hold zero (useful for quickly clearing registers or for comparisons) and R31 is dedicated for use as a link pointer for procedure calls.

In combination with the R3010, the R3000 gives an impressive 7Mflops (million floating-point operations per second) for single-precision floating-point calculations. With the use of a suitable optimizing compiler both chips can run simultaneously, without having to wait for each other; the seamless interface means that the two can swap data without interrupting their other processing tasks, almost as if the two were on the same piece of silicon.

MIPS places great emphasis on the importance of the compiler to the ultimate performance of the processor and the system. For a risc chip to get the most from its hardware it is essential that the compiler is designed hand in glove with the processor. Experience shows that as much as a 3× performance gain is realised in a risc system if the compilers are well designed.

Indeed, MIPS involved the operating system programmers in the design process. Consequently the R3000 is well suited to running C (and, in turn, Unix). The company also claims that this work avoids the usual speed/size trade-off that makes risc programs longer than an equivalent piece of code for a cisc processor.

Compilers are available for Fortran 77, Ada, Pascal, PL/1, Cobol (golly, does anyone still use it?) and of course C. There is also a full version of Unix and a real time operating system. This is easily the widest range of software support for any risc chip.

The R3000 is a very fast chip (topped only by the i860), with a well-designed architecture and an excellent software environment. With four years of sales, the device has a mature user base and a good deal of third-party equipment and support.

ACORN ARM

One of the interesting things about risc is that the designs haven't come from the semiconductor manufacturers but from computer companies (Sun, Hewlett Packard, IBM etc.) and now the British company Acorn has joined in. This device is the British hopeful of the risc world. Designed by Acorn (of BBC Micro fame) for the Archimedes computer it has been available as a component for two years.

The chip has a very simple straight-forward design. It is a 32-bit machine, integer only, with a load/store architecture. The register file has 27 registers: 15 are general-purpose and can be used by the program freely, the others are dedicated to particular system functions (status register, interrupt control etc.). It does illustrate the risc philosophy that such a powerful CPU can be so simple – it's a tiny chip with only 25 000 transistors (about 10% of the number in a 68020 and a lot less than the 1.2 million of an 80486!). It is manufactured in a conservative 3μm c-mos technology which, while reliable and cheap, is not very fast. The device was designed by Acorn in Cambridge and is manufactured by VLSI technology of Arizona.

The design does have one twist in it. Every instruction contains a four-bit test field: only if the test is true is that instruction executed. This is a very elegant idea, which makes programs much more efficient. According to Acorn the majority of jumps are skip types (i.e. *if* condition, *then* miss next instruction). There are 16 possible tests, including overflow, equal, not equal, greater than and negative. Obviously this reduces the number of jumps necessary in the program, which makes the pipeline more efficient by reducing the number of bubbles.

There is a four-chip set available: the VL86C010 is the processor, there's a memory-management and cache control unit (VL86C110), a dedicated graphics controller (which includes timing generation, a colour look-up table and three video DACs) and a digital i/o device with timers and the like. The four of these can be put together to make a complete system: just add memory and a program to build your own computer. There is no hardware support for floating point operations.

On a 10MHz clock, the processor gives about 6Mips – which isn't as impressive as it was three years ago. Despite the head start of being early to market, the chip does not seem to be a success. Few companies want to use it. It would be nice if it were to succeed, but given Acorn's marketing I don't hold out much hope.

The latest news is that Acorn has designed a new version. The VL86C020 is a 20MHz device with a creditable 4K cache on chip. This says Acorn, will triple the performance, giving a reasonable 15-20Mips.

Sparc

The sparc chip (short for Scalable Processor ARChitecture) was designed for Sun Microsystems by Dr David Patterson, who headed the research team at Stanford University that developed the philosophy. The chip was one of the first risc processors to be released and is fairly conventional in its design, but with a neat twist that makes it extremely well suited to running C and Unix.

It is a 32-bit device, with 50 integer-only instructions, operating in a single clock cycle on the internal registers (as usual this chip has a load/store architecture) and large pipelines on the external buses.

The device has a separate numeric floating-point coprocessor. The CPU extracts any floating-point instructions from its instruction stream and puts them into a separate queue to be executed by the coprocessor. It is possible to have several FPUs linked and running concurrently if necessary.

It's slightly surprising that this is an integer-based device, in view of Sun's strength in the engineering and work-station markets. Apparently the designers decided to aim for simplicity and stability in their first device. But the next version will be more powerful and will include its own floating point unit. Weitek, the company which specializes in making very high performance co-processors for other manufacturers' CPUs, has just announced the release of an add-on for the Sparc. Not only will this improve its performance, but such third-party support is a clear sign of the chip's credibility and success.

The architecture of the Sparc chip has been very cleverly designed to run procedural tasks (like C, Unix or Pascal) efficiently. It has an unusually large number of registers – 192 (in most risc devices, 32 has been adopted as the optimum number) – which are arranged as a succession of partially overlapping 24-register windows (**page 868**). Each window contains eight 'in', eight 'local' and eight 'out' registers, which overlap slightly: the 'out' locations of one window are shared with the 'in' registers of its successor, and so on. This allows functions to work very quickly indeed.

Merely by switching from window n to window n+1 a new procedure is started, possessing its own local variables (R8-R15), taking parameters and returning values with its calling function (through the out-in registers R0-R7) and able to pass parameters to its own subroutines through R16-R23. The call is quick because parameters need never be physically moved: merely by being kept in the appropriate register they will automatically be passed on. Compare this with the huge amount of Pushing and Popping of parameters and data that would be needed in using a chip with a smaller number of registers.

Unix is simply a large C program (according to Kernighan and Ritchie, of the 20 000-odd lines of code only the bottom 800 were written in machine code). Indeed, a C system is predominantly a C program; most of the language consists of function calls accessing ready-written C procedures that have been compiled and stored in the library. This is implemented through a great number of function call and return stages which impose a large overhead – packing and unpacking data, saving and restoring registers, sending parameters, returning values and so on.

Looking through the object code produced by a C compiler could be a revealing experience. If calling a procedure and passing parameters can be made even a *little* more efficient, the net speed gains will be dramatic. I have heard that this chip has run real world C programs up to five times faster than its rated speed would suggest. Of course this type of claim is difficult to verify, since so much depends on the particular program and the quality of the compiler's optimization. However I would not be surprised if there were some hard truth behind the hype.

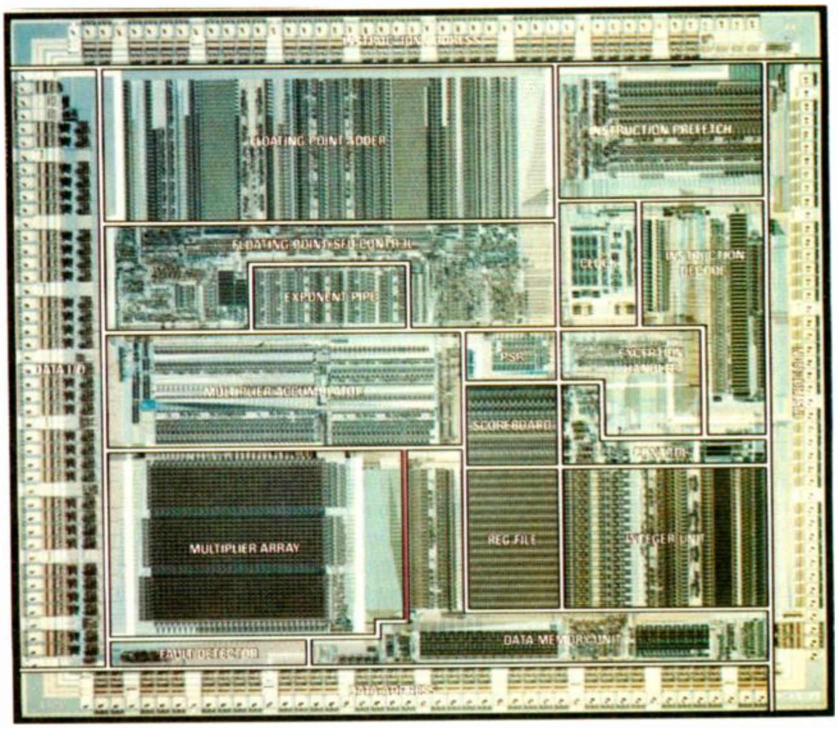
'Scalable' in the chip's name refers to an intriguing feature, that it is possible to reduce the chip's size (i.e. to adopt narrower line widths) with little effort or change. This definitely is not the case for cisc devices. The advantage is that it extends the life of the architecture, by making it easy to transfer it to newer, faster technologies.

The Sparc is now well supported in the market: Fujitsu manufactures a 10Mips version in 1.5μm c-mos; Cypress, using its own c-mos process, claims 20Mips; and Bipolar, using ECL clocks in at an impressive 50Mips.

Motorola 88100

Of all processor manufacturers, Motorola has the most to lose from these new developments. Its processor family, the 68×0 series, has always been successful in the high end of the market, being used in work-stations and super-micros. However these processor-intensive markets are precisely the area where powerful risc processors are set to make their biggest impact. It isn't surprising

continued on page 1106



CIRCLE NO. 137 ON REPLY CARD

PIONEERS

Lee de Forest (1873-1961): last of the great inventors?

W.A.ATHERTON

Although for a long time he did not have a full understanding of how it worked, Lee de Forest invented the triode, or audion as he called it. For nearly half a century it, and its descendants, dominated electronics. De Forest was also one of the earliest inventors of electronic circuits. Justifiably he could claim, therefore, to be one of the founders of electronics. Over 300 patents were filed in his name and many have regarded him as the last of the great individual inventors: but his own hope of a Nobel Prize was never fulfilled.

The name de Forest was of Huguenot origin. Lee's father, Henry Swift de Forest, was a Congregational minister and principal of a school for negroes in Talladega, Alabama. It was there that Lee grew up, having been born in Iowa at Council Bluffs on August 26, 1873. His mother, Anna Margaret Robbins,

Look here, de Forest – you'll never make a telephone engineer...

was the daughter of a Congregational minister.

A wealthy ancestor's endowment of a scholarship at Yale University enabled de Forest to study for a bachelor's degree in mechanical engineering and he was awarded this in 1896. He followed it with a Ph.D. in 1899 for a study of the reflection of electromagnetic (Hertzian) waves from the ends of parallel wires, possibly the first Ph.D. thesis in America on a topic closely related to radio telegraphy.

By the age of 16, de Forest had announced his intention of becoming an inventor. This ambition had not dimmed by the time he left university and he determined to win fame and fortune as an inventor, with Nikola Tesla as his idol. He has also been quoted as saying that Marconi and Edison were his inspiration.

On leaving Yale, de Forest joined Western Electric in Chicago at $8 a week. But because he was never enthusiastic about working for others it was not long before his interest in radiotelegraphy led him to seek to challenge Marconi, who by then was famous. De Forest wanted his own radio system, independent of Marconi's patents, and his own company. In fact he was to found several companies over the years but he lacked the business skills which would have enabled any to survive.

At Western Electric his tinkering with radio brought no official acclaim. One day, according to his diary, he was told, "Look here, de Forest. You'll never make a telephone engineer. As far as I'm concerned you can go to hell, in your own way. Do as you damn please."[2] He took the words literally and worked full time on his own system for the remainder of his fairly short time with the company.

His next employer had built a radiotelegraph receiver which de Forest dismissed as a "non-receiver set"[2].

In business

With an acquaintance, Smythe, who was also helping to finance him, de Forest filed for a patent in 1900 for a new radio detector which he called a "responder" and which he hoped would evade Marconi's patents. He then started his first company, bringing in another acquaintance, Freeman. Publicity was gained for their new system, which had a reported range of four miles. Then in 1901 there came the chance to demonstrate his system against Marconi who had contracted to provide ship-to-shore reporting of the America's Cup Yacht races. De Forest's trial has been described as a failure.[2] During the races he is said to have tossed Freeman's transmitter overboard!

Technically the detector remained de

Above: Lee de Forest (left) in England with John Logie Baird, the pioneer of mechanically-scanned television. This photograph was taken in October 1933.

Forest's big problem. Financially he moved on to bigger things. In 1902 a Wall Street financier helped him start the American de Forest Wireless Telegraph Company, capitalized at \$3M. Smythe and Freeman were left behind.

Early success was achieved with orders from the Army and the Navy and for a radio link between Costa Rica and Panama. But the company's grandiose plans led to its downfall. An American network was envisaged; over 90 stations were erected and others planned, but many never sent a message. Shareholders closed the operation in 1907 and sold its assets. De Forest was forced to resign, taking his patents with him. Amongst other things they covered the, as yet unused, triode.

A strange device like an incandescent lamp...

Immediately the De Forest Radio Telephone Company was formed, with a capital of \$2000 000. Again the Navy bought some equipment, with mixed success. Stock sales staved off bankruptcy and de Forest's talent as a showman maintained publicity. Broadcasts from the Eiffel Tower in 1908 and the first opera broadcast (starring Caruso) in January 1910 kept public awareness alive. Despite making some excellent equipment (the US Navy was its best customer), the company became bankrupt in 1911.

In May 1912, de Forest and his associates were charged with fraud over some of the methods used to promote the company. De Forest was exonerated but two of his colleagues were jailed. The significance of the new technology was not widely understood and the words of the government prosecutor have often been quoted, accusing the defendants of selling stock "in a company incorporated for \$2 000 000, whose only assets were de Forest's patents chiefly directed to a strange device like an incandescent lamp which he called an Audion and which device had proven worthless". That worthless device was the triode.

Towards the triode

The story of the invention of the triode is confused. De Forest's early attempts to design a new detector were frustrated by court cases for infringement of others' patents, e.g. those of Reginald Fessenden. Eventually he returned to an observation he had made in 1900 that a gas flame dimmed when sparks were generated by his induction coil. This suggested that a gas flame could be used as a radio wave detector. In fact he found that the effect was caused by sound waves from the spark, not radio waves.

Despite that, he maintained a "firm conviction that in the heated gases surrounding incandescent electrodes there must nevertheless exist a response, in some electrical form, to high-frequency electrical oscillations."[1] This conviction led to experiments with electrodes in the flame of a Bunsen burner, and with gas inside a glass bulb ionized by a potential between a cathode and an anode. In this way de Forest started to experiment with thermionic diodes, invented by J.A. Fleming in 1904.

De Forest apparently regarded the ionized gas inside the valve as essential. He wanted an incoming signal to trigger the gas from one conducting state to another, in a manner parallel to that achieved in the popular coherer whose resistance changed dramatically in the presence of electromagnetic waves. It was a long time before he accepted the true explanation of how a vacuum diode worked, based on O.W. Richardson's 1903 explanation of thermionic emission.

So in seeking to cause the trigger effect he wanted in the gas inside the diode, de Forest introduced a third electrode to which he applied the input signal. Although none of the many permutations of shape and size for the third electrode produced a very good detector, he found that the best was an open grid of fine wire. Hence the invention of what we know as the triode. De Forest used the term audion for both diodes and triodes.

Patent battles

Experts seem to differ as to whether de Forest actually began with Fleming's diode and then used the gas flame experiments to try to fight off the accusation of infringing Fleming's patent, or whether de Forest's account is the truth. De Forest was always sensitive to the possibility of a suit for infringement of Fleming's patent, which was owned by the Marconi Company. When the suit did come, Marconi won. Some accept de Forest's explanations of how he made his invention as being the way it was, others see them virtually as disinformation designed to protect himself against this possible suit.

The triode was invented in 1906 and a patent filed in January 1907. De Forest seems to have regarded it as a finished product and did not seek further improvements. He turned his attentions to radio telephony. For years the triode was simply another radio detector, sometimes better, sometimes worse than the more popular crystal or electrolytic detectors.

Lee de Forest, the American inventor whose amplifying device made the transatlantic telephone a practical possibility.

What transformed the triode into the basis of electronics were the improvements made by industrial laboratories following the discovery of how to use it to amplify and oscillate. These circuit inventions were made independently by several people in 1912 and 1913, de Forest being one of them. The arrival of the amplifier was of great significance to the telephone companies as well as the those involved in radio telegraphy. AT&T bought the repeater rights to the triode for \$50 000 in 1913 and later the radio rights as well.

Lee de Forest: one of the last great individual inventors.

The value of the triode as an oscillator was that it could be used to generate continuous electromagnetic waves for radio transmitters. Four men contested the patent rights to the invention, with de Forest eventually winning the legal battles. The longest patent litigation in American radio history was that between de Forest and Edwin Armstrong[3] over the invention of the feedback or regenerative circuit. When Armstrong won the first round in 1917, de Forest sold his patents and any future valve inventions he might make to AT&T for \$250 000. From then on he seemed to lose interest in radio, turning instead to talking pictures. The final legal judgement however went to de Forest, with engineers generally feeling that Armstrong had been let down.

Success

Once the triode had found important uses as an amplifier and oscillator, industrial scientists were quick to understand its mode of operation. De Forest's gas was evacuated to produce a high-vacuum device and a filament life of 1000 hours was achieved in 1913. Oxide-coated filaments increased emission and more new circuits were invented such as the push-pull amplifier (E.H. Colpitts, 1912) and the Colpitts and Hartley oscillators. The First World War provided further stimulus for improvements and use. A somewhat similar path was followed in Europe where Robert von Lieben patented first a diode (1906) and then a triode (1910).

In 1911, when de Forest's company was in severe financial difficulty, he took a job with the Federal Telegraph Company in Palo Alto, California. California then became his home.

Above all, de Forest was a prolific inventor, not a businessman nor a scientist. Amongst his other patented inventions were a high-frequency surgical cautery device, several types of microphones and loudspeakers, and stereoscopic and large-picture television. Naturally he received many medals and decorations but the decision not to award him the Nobel Prize is said to have left him heartbroken[4]. He seems to have had the knack of inspiring intense loyalty in some people, but antipathy in others.

For the last two years of his life illness kept him bedridden, almost totally incapacitated, and financially drained. He died on June 30, 1961, at his home in Hollywood, California, in his 88th year and just four years after his last patent was issued. His fourth wife, Marie, survived him. He was one of the last great individual inventors.

References

1. R.A. Chipman, *Scientific American*, Vol. 212, 92-100, March 1965.
2. W.R. Maclaurin, Invention and Innovation in the Radio Industry, Macmillan, New York, 1949.
3. W.A. Atherton, Pioneers – Edwin Howard Armstrong, *Electronics & Wireless World* November 1987, page 1111.
4. H. Gernsback, *Radio Electronics*, Vol. 22, Sept 1961, p.33.

Next in this series: Grace Hopper – pioneer of computer languages and software.

Tony Atherton is a Principal Lecturer at the IBA Harman Engineering Training College, Seaton, Devon.

My Life with the Printed Circuit, by Paul Eisler, edited with notes by Mari Williams. Dr Eisler's name is hardly a household one, even among engineers, though it certainly deserves to be. For it was he who invented and patented the printed circuit; and indeed in this book he claims to have conceived the integrated circuit too. Yet little thanks did he get for his idea. When he demonstrated a complete radio set built on a PCB to the production director of the Plessey Company in 1936, the invention was rejected. Apparently Plessey thought it cheaper and more flexible to use girls to wire up its radio sets – a monumentally crass decision in the same league as that of the record company which rejected the Beatles, and one which Plessey deserves to have its nose rubbed in at frequent intervals. But other bodies showed equal thoughtlessness and lack of vision, perhaps the worst being the Government's National Research and Development Corporation. The NRDC more or less gave away Dr Eisler's rights because it did not wish to see UK infringers prosecuted. Even so, Dr Eisler seems surprisingly lacking in bitterness towards his adopted country.

His story is an interesting one. It begins in pre-war Austria, where he was born and attended university; he left because, with a name like his, there was no prospect of employment anywhere in the Nazi sphere of influence. After a bizarre period spent in what is now Yugoslavia, installing radio receivers in express trains (the then equivalent of in-flight entertainment) as an agent of the HMV company, he eventually obtained a job in London as resident technical wizard for the Odeon cinema chain – only to be deprived of it when he was interned by an ungrateful country as a potential Nazi agent.

After struggling on with his printed circuits, which he saw as his personal contribution to military electronics in the fight against Nazi Germany, he progressed to an assortment of other inventions, with varying degrees of success. Packaged foods with built-in heating elements, for the diner in a hurry, may have failed to make the grade (the photographs include a curious picture of a dummy packet of fish-fingers with heating tape folded between the portions), but electric wallpaper for space heating in buildings did much better. It would have been still more of a success but for an unexpected national windfall of cheap natural gas from the North Sea, which suddenly made electric heating unattractive.

It is too late to make amends to Dr Eisler for the uphill battles he faced in obtaining his dozens of patents and defending them against the depredations of artful financiers and the unhelpfulness of apathetic bureaucrats. But perhaps we owe it to him to read his book, and to resolve to show just a little foresight should we ever find ourselves in the same position as that man as Plessey.

Associated University Presses (25 Sicilian Avenue, London WC1A 2QH), 170 pages, hard covers, £13.95, ISBN 0-934223-04-1.

MMIC – Monolithic microwave integrated circuits by Yasuo Mitsui (Mitsubishi Electric Corporation). This volume is one of a series of reviews (their subject areas are electronics, computers and communications, manufacturing technology, new materials, and biotechnology) which seek to overcome the language barrier by presenting an accessible English-language account of some aspect of modern Japanese technology. The author presents a survey of MMIC technology (eight Japanese companies, he says, are active in this field) covering manufacturing processes, circuit design and prospects for the future. His text is extensively illustrated with photographs and diagrams, and there is a 148-item reference list at the end. Gordon and Breach Science Publishers, P.O. Box 197, London WC2E 9PX; Harwood Academic Publishers, P.O. Box 786, Cooper Station, New York NY 10276; 127 pages approx. A5, soft covers, $47, ISBN 2-88124-2863. This book is also available through the Science and Arts Society, a book club specialising in high-level reference works, at the reduced price of $34; details from Harwood Academic Publishers.

Lithography in Microelectronics, edited by T.M. Makhviladze: *Proceedings of the Institute of General Physics*, Academy of Sciences of the USSR, Volume 8. This volume contains English-language versions of 11 specialist papers describing Soviet progress in fabricating sub-micron structures. Titles include "Simulation of latent image formation in electron lithography", "Mechanism of nonlinear change in characteristics of positive photoresists upon laser exposure", "X-ray lithography with synchrotron radiation", "Titanium disilicide films for metallization of VLSI circuit connections" and "Theoretical and experimental study of the Josephson Effect in submicron SN-N-NS structures". Published in the US by Nova Science Publishers Inc., 283 Commack Road Suite 300, Commack, New York 11725, 207 pages, hard covers, $75, ISBN 0-941743-30-6. This material first appeared in Russian in 1987.

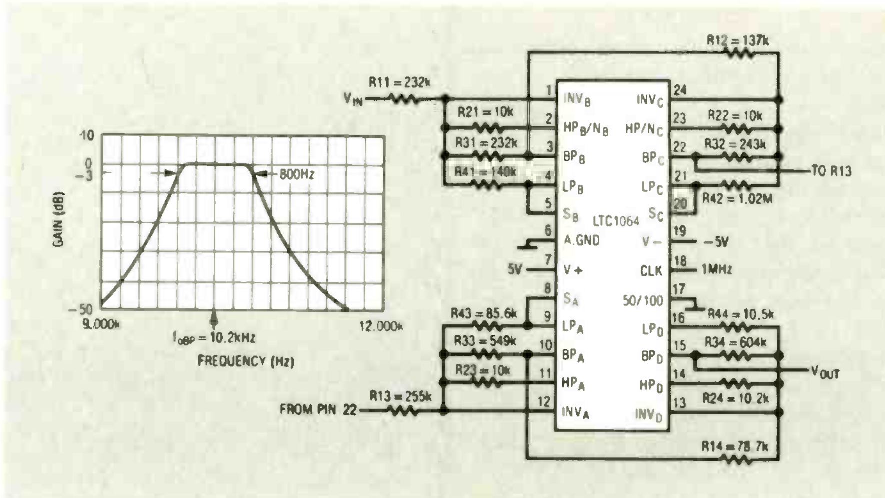
Guide to Commercial Telecommunications Services by Jeffrey Hsu. User's introduction to electronic banking, e-mail, teleconferencing and on-line databases: author describes what's on offer and how to gain access to it, with sample on-screen dialogues for many systems. Among the hundreds of sources mentioned in the book – most of them American – are many in the scientific and technical field, including the Institution of Electrical Engineers' Inspec system, described here as "one of the most comprehensive sources on computers, electronics, information systems and technology, and physics". Prentice Hall, 397 pages, soft covers, £26.05, ISBN 0-13-368879-8.

Filter design the easy way

In Application Note 27A from Linear Technology, the emphasis is on simplifying filter design procedure. It discusses two methods of designing bandpass filters from switched-capacitor building blocks – one using traditional non-identical sections and the second involving identical sections.

Design tables are included, one of which Linear Technology claims enables anyone to design Butterworth bandpass filters.

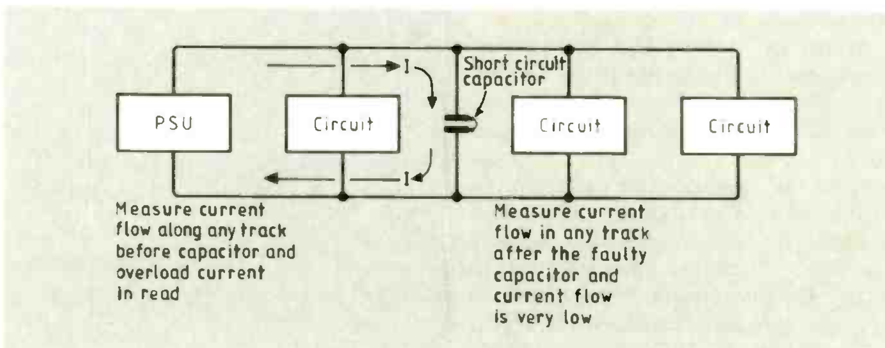
One of three design examples in the note is this eighth-order bandpass filter for 10.2kHz. *Linear Technology, Microcall, Thames Park Road, Thame, Oxfordshire OX9 3XD. Tel. 0844 261939.*



Fault finding with an ammeter

A current meter sensitive enough to measure the resistance of a PCB track is an invaluable fault-finding aid. For example, finding a short-circuited decoupling capacitor on a dense logic board is very time consuming by conventional methods, but with a sensitive current meter finding even a partially-shorted capacitor should take no longer than a few seconds – without track cutting.

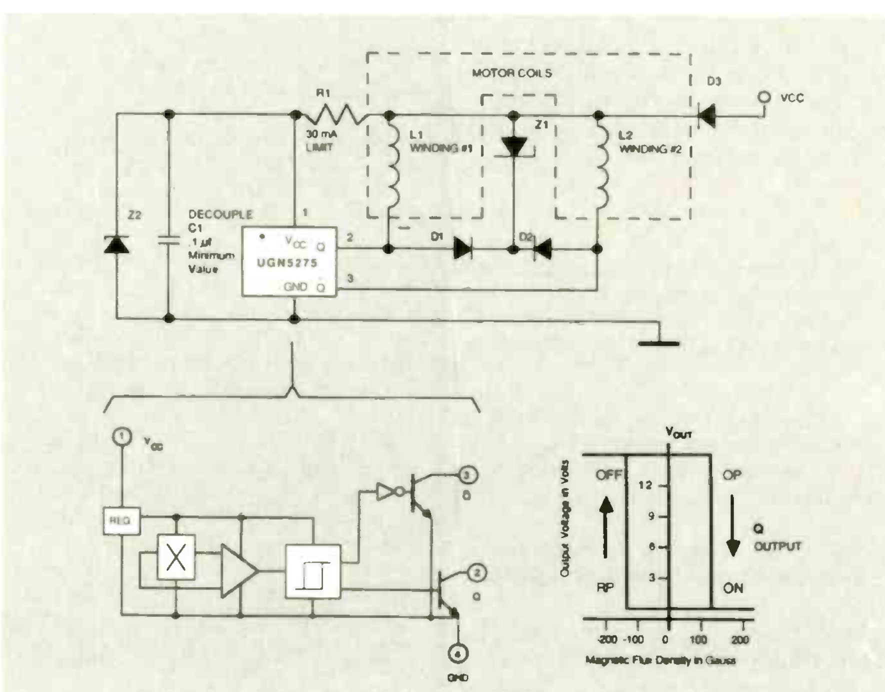
This application relating to the TL101A ammeter is outlined in a note from Transducer Laboratories. Among other uses suggested for the meter are cable-length determination and cable voltage-drop measurement. *Transducer Laboratories, Guildford Road, Farnham, Surrey GU9 9P2. Tel. 0252 733732.*



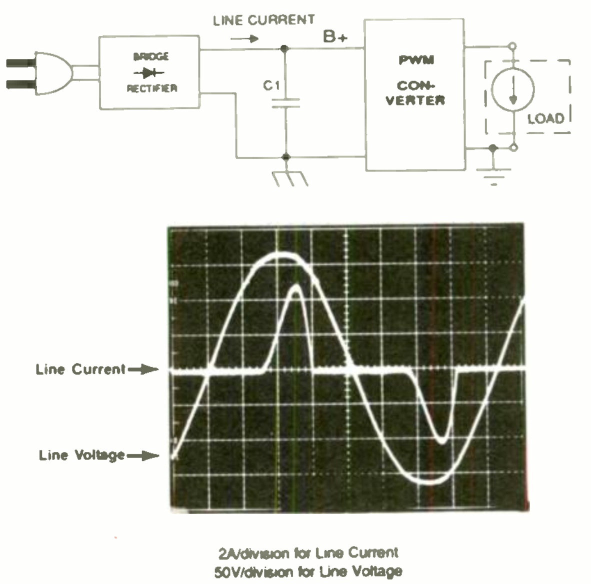
Power Hall device simplifies brushless motors

Design of small brushless motors is simplified by the availability of power Hall-effect ICs. Sprague's UGN5275/7 latching Hall-effect sensors can sink 300mA continuously and besides power-output transistors include a Hall voltage generator, an op-amp, a Schmitt trigger, and a voltage regulator. As a result, little more than one IC is required for commutation.

This circuit is the only one in the device data sheet, but guidelines for application are given. *Sprague Semiconductors, Balfour House, Churfield Road, Walton-on-Thames, Surrey KT12 2TD. Tel. 0932 253355.*

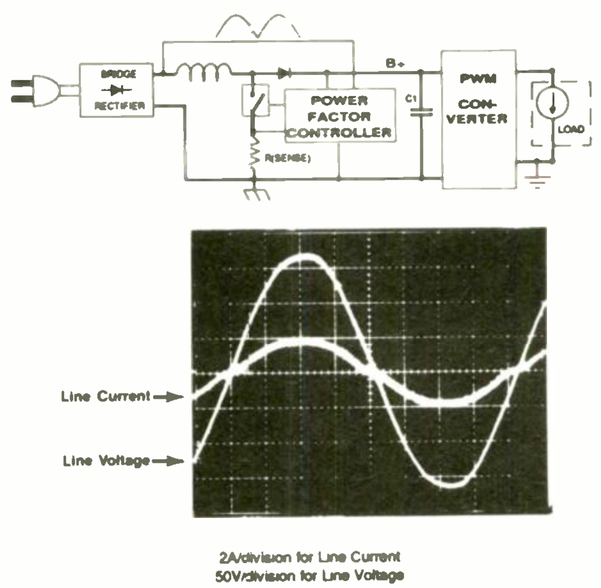


UNCORRECTED SUPPLY



Line Current is drawn during a short portion of the cycle in a conventional electronic power supply. (Power Factor = .7)

WITH ML4812 POWER FACTOR CORRECTION



Line Current is sinusoidal in a supply with Micro Linear's ML4812 Power Factor Correction. (Power Factor = .99)

Power-factor problems in switch-mode PSUs

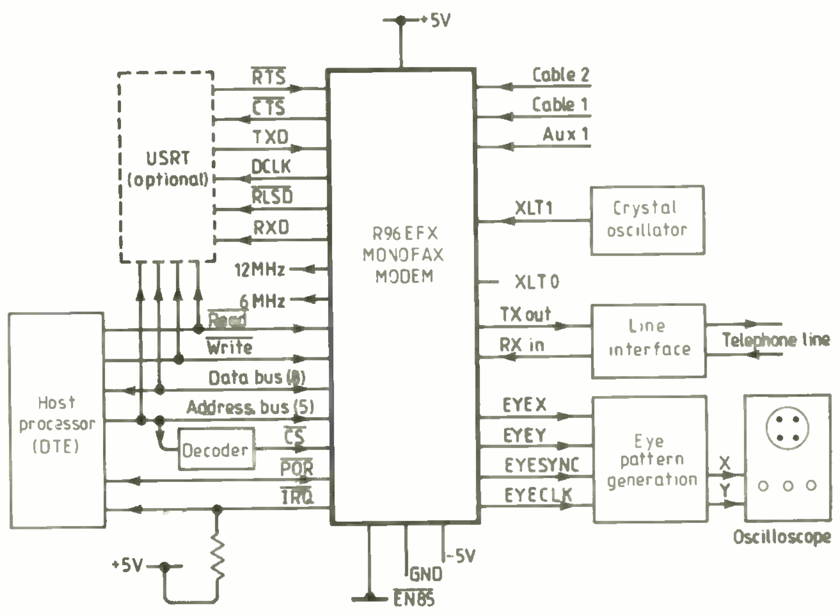
Most switch-mode power supplies have a poor power factor, and as a result draw inordinately high peak currents from the mains supply. In addition, harmonics produced by the current pulses develop substantial amounts of power-line noise and distortion, and since producing the harmonics takes power, efficiency of the supply is reduced.

These effects and a solution in the form of a new power-supply IC are discussed in an application note from Ambar Cascom. The chip – the ML4812 – controls a current-mode boost regulator that preregulates input voltage for a conventional pulse-width-modulated converter. A power factor better than 0.99 is achievable says Ambar. *Ambar Cascom, Rabans Close, Aylesbury, Buckinghamshire HP19 3RS. Tel. 0296 434141.*

Fax facts for modem designers

Communication standards are fine for users but they can cause problems for designers. For those of you considering new fax implementations, RCS Microsystems has produced an information sheet listing and outlining the relevant standards.

Addressess of standard sources are given, together with a list of fax modem products and application notes. *Rockwell, RCS Microsystems, 141 Uxbridge Road, Hampton Hill, Middlesex TW12 1BL. Tel. 01-979 2204.*



Data on this error-detecting fax modem forms part of a designer's information pack. Rockwell's R96EFX is a 9600 bit/s modem IC that conforms to CCITT recommendations V.29, V.27ter, V.21 Ch.2, T.3 and T.4; it covers the binary signalling requirements of T.30 too. Also in the designer's pack is data on other fax modem products and the information sheet mentioned here.

Polymeric sensor cable

David R. Fox of Focas Ltd describes a piezoelectric cable which could form the basis of a wide range of novel sensor devices.

In the September 1988 issue of *Electronics & Wireless World*, Peter Johnson introduced a piezoelectric cable manufactured from conventional piezoceramic materials such as lead zirconate titanate. The article quite correctly pointed out that a thick piezo-polymer was highly desirable from the senitivity point of view, but was difficult to manufacture because of a stretching stage necessary to render the polymer piezoelectric. However, a thick piezo-polymer has been available for several years under the name Vibetek-20 and is manufactured by a continuous process, resulting in a cost-effective solution to many electromechanical sensor problems.

The material used is polyvinylidene fluoride, or PVdF, and is manufactured as a continuous wire, with an outside diameter of 1.5mm and an active polymer thickness of 0.5mm (**Fig. 1**). It is mechanically flexible and can be wound around a mandrel as small as 5mm diameter, so that a wide variety of sensor shapes and sizes may be constructed from a continuous length. Vibetek-20 has a high piezoelectric activity and the coaxial geometry results in a high capacitance per unit length as well as offering a measure of self-shielding which is a particularly valuable feature when dealing with very small signals.

Piezoelectricity

The phenomenon of piezoelectricity occurs because of a special arrangement of atoms in the crystal structure of the material. These do not generally occur spontaneously (crystalline quartz is a well-known exception) and certain operations are necessary in order to render materials piezoelectric. For polymers these operations may include stretching the material by about four times at a suitable temperature, and the application of a high electric field. PVdF has

Table 1: Mechanical and electrical properties of piezoelectric coaxial cables

Property	Vibetek 20	PZT5A	Unit
Tensile strength	220	75	MPa
Density	2323	7750	kg/m^3
Specific acoustic impedance	2.7	33	MRayl
Relative permittivity 1kHz	12	1700	–
Cable capacitance	600	–	pF/m
Piezoelectric coefficient, 23°C,			
longitudinal	280	11.4	mV.m/N
hydrostatic	130	2.1	mV.m/N

been identified as the polymer which offers the highest piezo-activity when these operations have been performed.

It is the stretching stage which makes continuous production of thick piezoelectric polymer difficult. Thin piezoelectric PVdF films (7-40μm) have been available since soon after the discovery of the piezoelectric effect in the material.

Manufacture of Vibetek-20 with its 500μm wall thickness, however, is performed in three stages: an extrusion stage, a stretching and poling stage, and an electroding stage, all of which are continuous. By these means, a continuous piezoelectric coaxial cable can be manufactured in lengths of 0.5km or more.

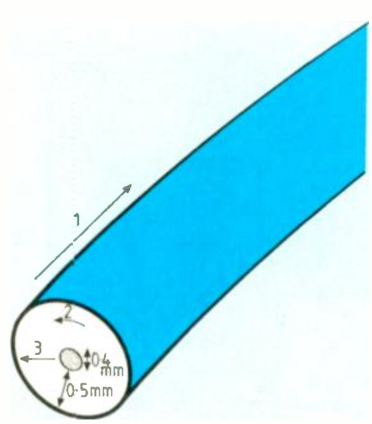


Fig. 1. Dimensions of the Vibetek-20 cable. Stress (for example, a mechanical stress in the so-called 1-direction, along the cable) results in a charge or electric field in the radial direction, the 3-direction.

Properties

Piezoelectric materials are anisotropic and are characterized by tensor quantities; but from the point of view of the sensor designer, and for the special case of a coaxial cable geometry, simplifications can be employed. Figure 1 shows a diagram of the cable with various directions labelled. The application of a stress in a given direction results in a charge or electric field being developed in the radial or 3-direction since this is defined by the electrode geometry. The mechanical input can be along the cable, defined as the 1-direction; or radially or hydrostatically, which means all directions at once. **Table 1** shows the longitudinal and hydrostatic voltage coefficients, together with some other important parameters.

Table 1 indicates that this piezoelectric cable is very flexible and has a low density. Its low acoustic impedance allows a better match to water, which is of especial benefit in acoustic sensor design. Although the PVdF material has a much lower permittivity than the ceramic, a high device capacitance can be achieved because the coaxial geometry of Vibetek results in a cable capacitance of 600pF per metre. Two significant differences between this cable and conventional ceramics are the high piezoelectric coefficients, and the extremely high tensile strength of the base polymer used in Vibetek-20. In particular, the cable can be stretched to a much greater extent than would be possible for ceramics. Thus at one extreme very high sensitivity devices such as hydrophones can be designed, and at the other extreme very high voltage generation is possible.

Applications

The mechanical flexibility of this cable, its high piezo voltage coefficient and its availability in long lengths offer sensor designers a greater freedom in the development of novel devices.

Two broad application areas are acoustics and impact sensing, and in acoustics the material lends itself to the underwater domain because it offers a very good match to the water.

A length of Vibetek-20 can be placed in the sea and will operate as a hydrophone, receiving any acoustic signals present. However, an increased acoustic sensitivity can be achieved by winding the piezo cable in a helix and potting the structure in a suitable elastomer. It is now possible to manufacture extended acoustic sensors greater than one metre in length and with sensitivities exceeding those of conventional ceramic-based devices. A bonus is the fact that the device is extremely shock-resistant. Frequency responses flat to within 1dB up to 5kHz or more are achievable.

In impact sensing, piezoelectric materials can be used on vehicle bumpers, on automatic doors, on missiles and on pressure mats, to name only a few applications. **Figure 2** shows the signal generated by the impact of a 60g steel ball dropped from 20cm on to a plaque of material containing a spiral of Vibetek-20. No amplification has been used: the cable was connected directly to the oscilloscope (input impedance 1MΩ). Hitting the same plaque with a hammer results in signals of several hundred volts, whilst experiments involving a 0.5kg mass striking Vibetek-20 at 500m/s show that the material can generate voltages in excess of 1500V. However, even finger pressure can generate usable signals, as a simple calculation shows.

Assume that we apply a force equivalent to, say, a 200g weight over a length of about 2cm of the cable. This is an area of approximately 10^{-4}m and the pressure experienced by the cable is therefore about 20kPa.

Although the pressure is not applied hydrostatically, we will take that piezo-coefficient as an approximation. Multiplying this coefficient by 0.5mm, the thickness of the piezoelectric layer in the cable, results in a figure of 65µV/Pa. Using the applied pressure we have obtained, we arrive at an output voltage of 1.3V. In fact, the situation is a little more complicated: the rest of the Vibetek-20 cable over which no pressure is applied acts as a potential divider; the output calculated is a no-load output; and no account has been taken of the circuit time-constant.

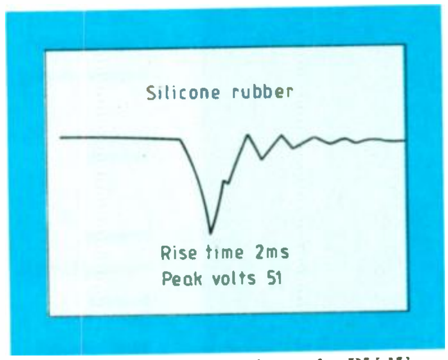


Fig. 2. Voltage output from the PVdF cable on the impact of a steel ball.

The cable is almost totally capacitive, with a value of about 600pF/m (Table 1). There is a resistive component because the material is piezoelectric, but this can be ignored in simple circuit analysis. A sensor is therefore modelled as a voltage source in series with a capacitance as shown in **Fig. 3a.** It is clear from this diagram that the input impedance of the preamplifier has a direct bearing on the frequency response of the system, since the circuit acts as a high pass filter with a corner frequency determined by the RC combination.

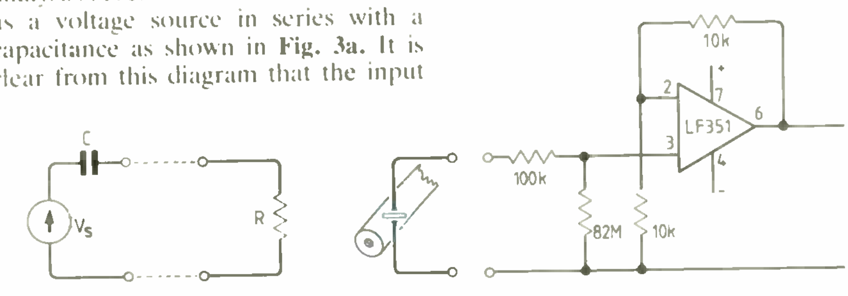


Fig. 3. Sensor model (a) and a possible preamplifier design (b).

Seen in this way, it is evident that preamplifier design must go hand-in-hand with the mechanical sensor design. Thus if it is required to sense a signal whose lowest frequency is 1.0Hz and the sensor length is 1.0m, a preamplifier with an input impedance of greater than 270MΩ will be required. On the other hand, if only signals above 10kHz are of interest, the input impedance need be only 27kΩ.

Figure 3b shows a tested circuit which has an input impedance of about 80MΩ. It is necessary to include a parallel bleed resistance to provide a DC path to earth when employing operational amplifiers in the non-inverting mode with capacitive sources. If large voltages are expected, as may be the case under high impact conditions, it is wise to include some back-to-back diodes to protect the input of the preamplifier.

Sensor design

Sensor design using Vibetek-20 requires a different approach to that employed for conventional piezo-ceramics. The sensor can be modelled as a voltage source in series with a capacitor which represents the region of the mechanical input, and a further parallel capacitor which represents the remaining unstressed sensor cable. As a result, frequency-independent voltage division occurs and the signal appearing at the end of the sensor cable is attenuated. Thus, in most cases it is important to apply the mechanical input over the whole length of the cable.

The type of bonding or potting material used with the sensor cable is important. Piezo-ceramics are so dense and rigid that the bonding or potting materials have very little effect on the overall response to mechanical inputs. But with PVdF, it is possible to tailor the response by choosing more or less rigid materials in which to embed the cable. For example, the steel ball test described earlier generates a signal of about 50V peak with a rise-time of about 2ms when the sensor cable is embedded in a soft material such as silicone rubber. The same test on a plaque made from a rigid epoxy results in a peak signal of 7V, but with the rise-time decreased to 125µs.

Other major applications include vibration monitors, intruder alarms and musical instrument pickups. The material has been used in non-destructive testing, in a breathing monitor and as a 'bump' detector in the fruit and vegetable packaging industry.

The self-shielding properties of the cable result in a system resistant to electromagnetic interference. ■

Vibetek is a registered trademark of Focas Ltd, Unit 4, Cheney Manor Industrial Estate, Swindon, Wiltshire SN2 4BE; tel. 0793-513200.

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CIRCLE NO. 167 ON REPLY CARD

Who goes to university?

Your September editorial, "A nation of hairdressers", contains an estimate of the number of children who should statistically be suitable for university education, an estimate which is consistent with the criterion of an IQ of around 120 or above (on the usual assumption of a gaussian distribution with a standard deviation of 15%).

I do not disagree with this; although the cause of IQ is controversial, as to the relative importance of environment and genetics, there does exist a stable statistical distribution. But when I first looked at university numbers (in the 1950s) I assumed that only half those *qualified* would *wish* to go to university. The proportion is no doubt greater now, but motivation is vital to success.

I once tried to find a correlation between A-level qualifications on entry and class of degree achieved in a university department (of electronic engineering) and concluded that there were only two safe deductions: that no student entering with less than three Cs would be likely to achieve first-class honours and that none with at least one A would be likely to fail. Even these weak correlations are expressed in the form "would be likely to" because human behaviour can be affected by so many things, e.g. health, environment or personal relationships, that it is impossible to predict it precisely: one says that a young person "shows promise" but it remains to be seen whether the promise will be fulfilled.

On the National Curriculum one already hears cries of "How can we fit it all in?" while politicians add to the pressure by urging the extended teaching of more than one foreign language. I am one of the generation who went through what were then called grammar schools. We had slightly more class hours per week (including Saturday mornings) and much more homework than is usual in comprehensive schools. At what age should one be taught that achievement comes through work?

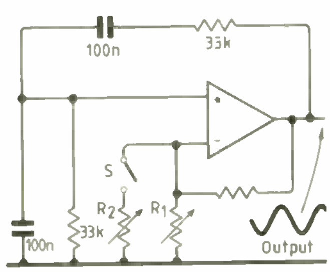
You may get a protest from hairdressers! Seriously, though, I have suggested elsewhere* that the least able cannot expect to find employment in personal services because the customer would not accept being served by such a person. They cannot become road-sweepers because roads are now swept by machine, so there are few opportunities for the uneducated.

D.A. Bell
Beverley
North Humberside

* Employment in the Age of Drastic Change, Abacus Press, 1984.

Wien oscillator amplitude

Recently, I needed to obtain a low-distortion, full-wave-rectified sine wave of accurately controlled amplitude at a frequency of about 50Hz. I use an op-amp Wien oscillator, a precision full-wave rectifier and an amplifier to compare the average value with a DC reference voltage. This produces an amplitude error voltage which controls the oscillator output by varying the bias on a fet in the oscillator gain-setting network. The problem is: how long does the oscillator take to reach a given amplitude?



In the circuit shown, it would be easy to adjust resistors R_1 and R_2 so that with S closed, oscillations doubled in amplitude every second and with S open, halved in amplitude every second. If, at some time, the instantaneous amplitude were 1V and S were to be opened, the amplitude would decay to 1mV after 10s. If the switch were then closed, the amplitude would rise to 1V after a further 10s. If, however, S had been open for 24 hours instead of 10s, one would not expect to have to close it for 24 hours to get back to 1V, so how long would it take?

My circuit always seems to take the same time to reach a given amplitude, but I see no way of calculating what the time should be. Does anyone have any ideas?

It would be best to assume ideal noisy components but to ignore switch-on transients in the op-amp to calculate a probable time. Switch-on surges would then serve to reduce this time which could be used as an upper limit.

Peter F. Vaughan
Lynton
North Devon

Cad, units and scratched diodes

I entirely agree with almost everything that Adrian Espin says in his September article "Who needs electronic circuit analysis?". The inability of graduates to analyse a simple circuit is not new; I met this over twenty years ago. Admittedly, this was in recruiting engineers for the consumer products industry, a sector considered beneath the dignity of many of the better graduates in this country, but not in most others! The only point of contention is that using cad to analyse such a simple circuit ought to be equivalent to using a calculator to add 1 and 1; a development engineer cannot perform properly if helpless without constant machine support. Many of the best design ideas arrive at bath-time or on other equally private occasions and can be better nurtured or rejected if one has decibel, log. and trig. tables (2 or 3 figures) in one's head.

Apart from the rather over-dramatic title of Colin White's article on units in September, it is a very helpful piece. It should be noted, however, that while the timber industry invented the '30cm unit', it was forestalled in the pages of *Wireless World* by Free Grid (or was it Diallist?), who proposed a unit of 1barefoot = 29.9792458cm, so that the velocity of light *in vacuo* would be exactly 1GBt.s^{-1}. In Mr White's terminology 1Bt would be 1nanoasyl.

Mr MacLean's p-n diodes (September Letters) are inherently sensitive to light, but the manufacturers usually take care to prevent sufficient light reaching the junction to cause problems – except in photodiodes, of course! Early diodes had only an external coat of paint and much trouble was caused by pin holes or scratches. Either Mr McLean has faulty diodes or his application is abnormally sensitive in some way.

J.M. Woodgate
Rayleigh
Essex

Units

Colin White, in his September article "Electromagnetic units in chaos", certainly justifies his title, but offers no explicit criticism of the SI units, merely referring to them noncommittally as "our present SI system". There are two objections to this system.

The first is that an attempt to make a current measurement. Using only the equation $dF/dz = 2C_m I_1 I_2 r^{-2}$ soon runs into difficulties. This is partly because all currents flow in closed loops and in this simple non-vectorial form the equation gives no idea of how the contributions to the force from the return sections of each loop are to be calculated, and partly because although currents consist of charges in motion the fact that the electrostatic forces between those charges must be subtracted off is not explicitly stated. However, both these difficulties can be overcome; it was the development of the current balance as the primary device for providing a standard current that prompted the choice of current as the basic electrical unit.

The second, more fundamental objection was stated in my letter of September 1988. The SI system incorporates a dimensional distinction between E and D (and between B and H) not found in the earlier systems, a distinction which is unphysical. It arose because in the development of the Giorgi units (precursors of the SI units) certain equations from the old electrostatic system which were taken over unchanged included suppressed dimensional factors, in effect introducing a two-tier system of electrical charges and associated field vectors, with E and P in different tiers. It was then found that the form of the equation linking E, D, and P which is derived from Gauss's theorem could be simplified by assimilating the dimensions of D to those of P. This "simplification" led directly to the rash of different dimensions afflicting the electromagnetic field vectors in the SI system, which needlessly complicates conversions between the old and the new units.

C.F. Coleman
Grove
Oxfordshire

Open letter to the recording industry

In the 1970s, great advances in high-fidelity sound equipment took place. There was also an appalling standard of pressing quality on most records, albums in particular. We saw the recording industry have its knuckles severely rapped, which brought about a considerable improvement in quality in an attempt to save the industry's profits in the face of the increasing popularity of the tape cassette.

Are we now to repeat the fiasco with compact disc? There has again been a huge leap forward in sound reproduction, CD players costing, on average, around £250, with features such as multi-oversampling and bit multiplication. We are promised 100dB or more of signal-to-noise ratio, −95dB harmonic distortion, zero crosstalk, wow and flutter and hum, and superb frequency response.

Why then is it that, after paying for the latest digital CD player, we find that not one CD in the charts even nearly approaches the performance of even a standard player? I have found that the typical signal-to-noise on many chart CDs is a little over 60dB (about the same as a good vinyl record). In addition, some have levels of 50Hz hum, again typically −60dB, that should have been banished from all recordings years ago. The best CD I could find (Paul McCartney, Flowers in the Dirt) provides a mere 75dB signal-to-noise ratio – some 25dB short of the promised magic 100dB.

The current state of CD recording quality makes complete nonsense of the latest state-of-the-art technology fitted to current CD players. CDs are not particularly cheap and I believe the public are being totally misled by the promised improved quality when the quality of recordings is so poor. You people in the recording industry must put some of those huge profits back into refurbishing your recording equipment to a standard to at least match today's hi-fi systems.

Les Sage
Sage Audio Electronics
Bingley
Yorks

R.I.P. cold fusion?

"Need we say more?" (*E&WW* Research notes, p. 847, September 1989). If the UKAEA at Harwell spend £320 000 and conclude that cold fusion is dead, then the judicial authority of British Science has put on its black cap and death must follow – that is the way of Nature – at least in the UK.

The August 10 issue of the local newspaper tells us in Southampton that cold fusion has the "US seal of approval" because a Salt Lake City panel in Utah have "released $4.5 million to set up a national institute to investigate the claims of Professor Fleischmann of Southampton University". This follows the report in the *Financial Times* some weeks before, advising that General Electric of USA is now taking an active role in cold-fusion research initiated by the Utah experiment of Fleischmann and Pons.

The layman might wonder how Harwell's failure to detect enough neutron emission leads to the no-fusion-in-Utah conclusion when Harwell scientists firmly believe that fusion is occurring in the sun, bearing in mind that experiments in South Dakota have failed to detect enough neutrino emission. No neutrinos should surely mean no solar fusion, unless we live by double standards.

In science, we have a tendency to believe what we want to believe, especially if we have some special knowledge and it saves us the trouble of learning something new. I am no exception and, if only because my theoretical research assures me that there are no neutrons in the deuteron, I can accept "cold fusion" with no neutrons; see my paper "The Theoretical Nature of Neutron and Deuteron" in *Hadronic Journal*, vol. 9, pp. 1290-1306, 1986.

The Harwell experiments summarized in the *E&WW* Research Note were so numerous that they led to the "Need we say more?" question. But more must be said: a computer result is as good as the skill and imagination of the programmer and his knowledge of how the computer can be made to work and so it is with experiments. If the computer is an analogue computer containing no "neutron" features and the programmer assumes it to be digital and neutron orientated, the programmer is hardly likely to succeed.

The Harwell scientists are not reckoning with the possibility that entry of a deuteron from a light-atom environment into a heavy-atom environment involves a vacuum energy fluctuation of several MeV, enough to trigger the fusion reaction, without needing or producing neutrons. The deuteron has a graviton field and palladium has a supergraviton field. There is a phonon resonance condition which is particularly sustained, in advance of the transition from graviton to supergraviton, which causes the energy fluctuation when a deuteron plus one palladium atom has a combined mass which sums to that of one graviton plus one supergraviton. Another incoming deuteron has to meet up with this short-lived resonant deuteron state for fusion to occur.

Supergraviton resonance on its own can, incidentally, explain "warm superconductivity" when a perovskite molecular group, such as La_2CuO_4 or Y_2CuO_4, has a mass that matches a near multiple of the supergraviton mass (102 atomic mass units). This superconductivity feature is described in a published UK Patent Application No 2,210,870A, dated 12 October 1987, where it is also shown that the lower graviton state resonates with 6.6 atomic mass units. The cold-fusion resonance occurs because 102 plus 6.6 is very nearly equal to 2, the atomic mass of the deuteron, plus 106.4, the atomic mass of palladium.

H. Aspden
Department of Electrical Engineering
University of Southampton

Cold nuclear fusion

I read with interest, but no surprise, that the Harwell team had failed to find any evidence of room temperature fusion. We know already that cold fusion can take place (see Cold Nuclear Fusion, Johann Rafelski and Steven E. Jones, *Scientific American*, July 1987) though it works better at an optimum temperature of 900°C. It is not unreasonable to suppose that an improvement on this will eventually be found.

We should not forget that the method being pursued by Harwell and sister institutions is at least 40 years old in concept, and that an enormous organization siphoning off billions of public money is built on it. The careers of tens of thousands of scientists and of top administrators with considerable political influence are at stake. If this attempt at room temperature fusion had proved a success then at the very least, we would have heard nothing about it. We can only wait to see what reports are issued by other less interested organizations, and urge that original thinking and research continue in spite of the risk of overt or covert opposition.

Keith Wood
West Derby
Liverpool

de Sitter stars and the ether

If a distant binary star system is rotating in a plane which includes the Earth, then astronomers should see the image of the stars oscillating back and forth with an amplitude equal to the subtended star system diameter, but only if the velocity of light were constant in all reference frames. W. de Sitter[1] pointed out in 1913 that if this were not so, for distant binaries of moderate angular velocity, light from the receding member of the binary would be slower by 2v than the faster component from the approaching member and ultimately the "fast" light would overtake the "slow" light and get to Earth before it; thus an earlier event at the star would register at Earth after a later one (**Fig.1**). Since binary stars were known and such phantom appearances and disappearances had never been reported, this was taken as proof of the constancy of the velocity of light. It has remained a major proof as it does not depend on the interpretation of terrestrial experiments such as Michelson-Morely and any theory of light and ether would have to address it[2].

J.G. Fox[3] remarked that the Universe contains large quantities of material capable of scattering light and that light from a de Sitter star would be intercepted on its way to Earth, preventing the de Sitter effect from occuring. Clouds of small particles permeate space and form a "screen" on which the oscillation of the distant binary is relayed at constant light velocity: light received at Earth would have been forward-scattered from an intervening dust cloud. Thus, though the effect is unlikely to be observed at optical frequencies, the Rayleigh Law fourth power gain at 21cm over 500nm would predict some 10^{23} times less scattering at radio frequencies than in the visible. Radio waves might get through unaffected[4].

In neither paper did de Sitter give a formal solution for his star: Relativity was in full swing, the effect had not been seen. The system has to be solved parametrically. Considering one half of the binary for simplicity (**Fig.2**), it can be seen that for uniform angular velocity ω in a circle of radius r the displacement y of the star is

$$r \sin \omega t_s \qquad (1)$$

and the arrival time at Earth t_e of light leaving at t_s is

$$\frac{D+(r \cos \omega t_s)}{c+r\omega \sin \omega t_s} \qquad (2)$$

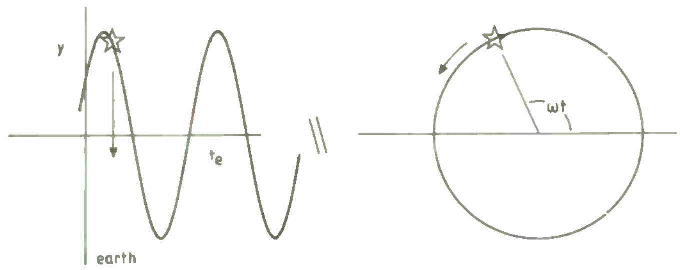


Fig. 1

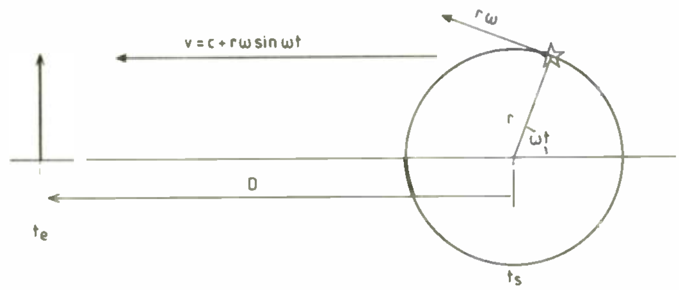


Fig. 2

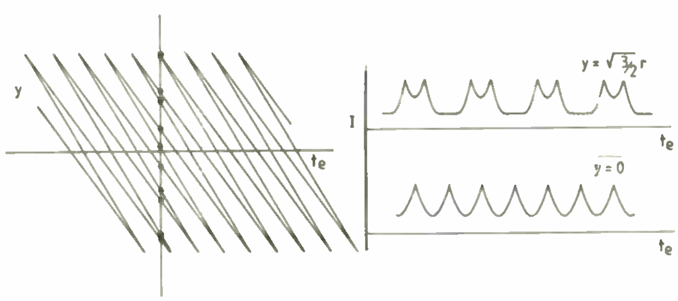


Fig. 3

where D is the distance of the system. A graph of y versus t_e gives the situation at the Earth. A terrestrial observer will see an array of periodically spaced phantom star images, like ducks in a shooting gallery, proceeding across the aperture of his telescope, appearing at one end from nowhere and disappearing suddenly at the other (**Fig.3**).

The behaviour of the phantoms can be exactly described[7], their lateral velocity being

$$U = \frac{Vv^2}{cv - Dwv - V^2} \qquad (3)$$

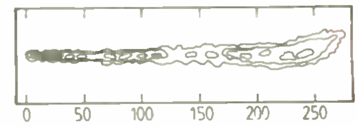
Under certain circumstances they move faster than c, ($v = c + rw \sin \omega t_s$; $V = rw \cos \omega t_s$).

The number of phantoms in the field and the source enery enhancement is given by

$$N = \frac{4r\omega^2 D}{\pi (c^2 - r^2\omega^2)} \pm 1 \qquad (4)$$

and there are two types, fast and slow.

For weak radio signals, radiotelescope interferometers are often used and high resolution is obtained by having very long baselines. Such a system, at low resolution, might[5] display the de Sitter phantoms as a periodic signal, a pulse, as the moving phantom array came in and out of phase with the antenna elements whose sampling phasor pattern defined the focus of the interferometer. A small rotating binary would seem as large as its binary radius, N times more intense, and pulsing. Focused off-centre, the pulse will be a doublet or pair; there should also be a pseudo-Doppler shift in the apparent wavelength dispersion versus displacement, long waves arriving later. This type of low-



NGC 6251
VLA 1410MHz

resolution behaviour may be of interest in connection with pulsar and other variable sources.

With regard to higher-resolution telescopes it is of interest that the lateral phantom velocities can be greater than c since this is a situation pertaining in the recently discovered fine structure of quasar sources. Radio signal density maps of some quasars obtained with long baseline interferometers have shown discrete objects, now called superluminaries, which are roughly equidistantly spaced and move across the long axis of the quasar field at speeds which can be in excess of c. The object NGC6251 shows on a VLA radio map at 1410MHz as a long thin stripe of small spherical point sources, doubled up at intervals which are roughly the same[6]. It is likely that these elements are in motion across the field from other studies of similar systems[7].

Are these de Sitter phantoms? If the ether exists then the effect should occur and should be sought at long wavelengths. Recent cosmological discoveries may have revealed it already.

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We will provide our derivation of the phantom equations for anyone interested.

Feedback and fets

Having just read Ivor Brown's letter in the July 1989 issue, I feel that the matter of slew-rate limiting needs a little more ventilation. I quite agree that in the amplifier system he describes, the slew-rate of the early stages has a marked effect on the distortion produced. However, to bring this about, he has had to assume a dead-band effect in the output stage; in other words, for small signals there is no output at all, as in a Class-B stage with zero quiescent current. Since much of the design work done on amplifiers in the last thirty years has been aimed at eliminating such gross crossover discontinuities, I must admit that I am inclined to view the demonstration as tending towards the not very useful.

The sharp spikes seen on the distortion residual of every under-biased Class-B amplifier are a demonstration of this effect. Improving the slew-rate of the early stages will make these spikes more narrow, but will not reduce their amplitude, and this would be considered a faulty or maladjusted amplifier rather than one under-designed for slewing. Increasing the quiescent current reduces the height of the spikes until they merge into the main body of the distortion products, and in fact this is the only reliable way of setting quiescent current. With it correctly set, a well-designed output stage will have only very small slope changes around the crossover point, and the early stages are not called upon to make particularly rapid adjustments to servo-out these errors. Clearly, with poor design slew-rate could be a problem, but then so could almost everything.

To turn to the bipolar/hybrid output stage, the driver transistors do indeed operate in Class AB, but I doubt if these relatively fast T05 devices have a bad effect on the crossover behaviour; all that can be said is that the stage as a whole is remarkably linear without any overall feedback. My own view is that the poor matching of the not-so-very-complementary mosfets around the crossover region is probably the cause of what crossover perturbations can be seen. I have tried Class-A drivers with AB bipolar output devices, and there seemed to be no benefit to be had.

Finally, it might be valuable if all of us provided more measurements in articles and letters, as otherwise comparison and reasoned discussion are very difficult. In particular, designs are often labelled "low-feedback" or "lashings of feedback" without specifying how much. While measuring open-loop gain is not always easy, the results should be highly informative, and perhaps Mr Brown will reveal the results for his design in his forthcoming article.

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Motion through the ether

It should be obvious that even if E.W. Silvertooth (May, 1989) and those of similar thinking are on to something, most of Relativity is *not* on its way to the scrap heap, and time spent on its study is not all wasted. For an analogy, consider the designing of some large civil engineering project. Pretty certainly, when it is put up all verticals will be checked with spirit levels or plumb lines (or some high-tech equivalent). But hang on, this planet is a spheroid, so the verticals will not be quite parallel. Is spherical geometry used, then, to design the thing? I doubt it. Good old Euclidian is much easier to manage, and any corrections can be calculated simply at the end.

With an absolute reference frame you must account the rotation of the planet, its motion around the Sun, the Solar System going round the Galaxy... Or you could do the donkey-work assuming a relative reference frame and at the end look up some standard tables to see what to add and decide whether it is significant. The figure of 378km/s given in "Motion through the ether" is about 5/40ths of 1% of the 300 000km/s it is worked from. The reason that I put the fraction in that form is because it compares readily with the roughly 3/40ths of 1% by which the rounded 300 000km/s varies from true c. It should be noted that these fractions are not cumulative with each other, but one will be within the other.

To explain certain aspects of the Big Bang, some physicists have depicted for us an ether where particles come into existence from "nothing". These "virtual" particles appear in pairs of matter and antimatter, and annihilated again almost instantly. Annihilations create energy but "appearances" absorb it, and charges always balance, so normally there is nothing to see. But come extend this idea a little. If you introduce a bias somewhere then some pair-halves will be absorbed leaving their partners loose. What are these to do? Annihilate with the partners of others, which in their turn... In fact the bias will propagate. If large amounts of energy can be shared out, then the propagation will appear and behave as a wave, but set things up right and you will catch particles. Sounds familiar. And it doesn't need excusing as just an intellectual "tool".

To be appreciated here is that any particles detected will have actually originated just in front of the detector. Similarly, particles coming off the source will be absorbed almost immediately. Energy passing from source to detector will be literally relayed by default. The speed at which it happens will depend on the speed at which the virtual particles appear or can be stimulated to appear. Maxwell, I think, had something to say about how electric and magnetic waves have to interact. Only a certain critical speed, which we now know by the letter *c* of course, will do. If the above is what is actually going on when an electromagnetic wave propages then a number of things follow. One is that no matter how fast original particles comes off a source the resultant wave will propagate at the speed of light, c, as we know it. Imagine that you and two colleagues are in a large hall. The one furthest away from you sneezes violently. Now, anybody with half a bit of knowledge about such things knows that the air in his breathing passages will be moving at supersonic speed. So what difference will the direction in which he is facing make to the time lag between your other colleague hearing the sneeze and your hearing it? Given that the other colleague is not too close to the sneezer, *none*, of course. The actual air motion will be dissipated in the immediate vicinity of the sneezer, and thereafter the shock wave will propagate at the prevailing speed of sound. Another thing that follows is there is actually no entity that can be called a photon. Set up a line of dominoes, then push one to topple the others. What thing off your finger reached the last in the line? Could you weigh it?

Of course, few things can make an alternative more unattractive than something generally accepted that seems to work. Particularly when the alternative clearly cannot be too alternative. Relativity gets most effects near enough right, so much of an alternative scheme can look like an exercise in changing labels. The grip of Relativity is such that if an experiment should produce a result at variance with it then the experiment is immediately the suspect party.

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ELF reception

It was interesting to read recent articles on non-parabolic satellite antennas. Readers may like to know of a novel experimental rig being used by a friend of mine – an RF engineer with a consuming interest in ornamental gardens.

He has on his estate (he worked for a few weeks as an accountant before turning to engineering) about 350 garden gnomes in a variety of colours, each fitted with a small matching woolly hat sporting a large metal bell. With the aid of a theodolite and a long piece of 28s.w.g. constantan wire he has been able to adjust the position of each gnome by up to $\pm\lambda/2$ to constructively combine the diffracted reflections from the bells at a focus in the funnel of an old galvanized watering can hanging from the potting shed, inside which he is able to put his feet up in front of the television without fear of interruption from his wife.

Reception of Astra is excellent and he is now retuning the gnomes to be ready for transmissions from Olympus, though he suffered a setback when six of the elements were unexpectedly pulled into the lake by a large goldfish and disappeared. He reports that the tolling of ghostly bells can be faintly heard when the water is choppy...

Bob McGregor
Hitchin, Hertfordshire

Has he thought of selling the idea to BSB? – ed.

Contriving parallel I/O on the IBM PC

Mike Hale describes a method of providing a general-purpose TTL interface via the parallel printer port while maintaining access to a printer on the same port

Unlike many personal computers before it, the standard IBM PC is not equipped with any obvious unallocated general purpose input/output ports. Peripheral equipment, which may only need a few TTL signals to control, must generally be connected to an additional I/O card.

But a parallel printer port is installed as part of the base level PC specification on most machines, providing a standard hardware interface from the smallest 8088-based lap-top to the latest 80386 machines.

The parallel printer interface used on the IBM PC XT/AT sets the standard which all "compatible" manufacturers have to follow. Signals are TTL-level presented on a 25 pin D-type socket. Apart from this unfortunate choice of connector, it is directly compatible with the "Centronics" standard printer interface.

IBM's design, detailed in the Technical Reference Manual for the PC/AT, uses standard LSTTL devices. **Fig. 1** shows a typical PC-compatible interface design. PC compatibles may not use LSTTL, but the interfaces to the PC bus, and 25 way connector, will present similar signals.

To the PC bus, the printer interface appears as three parallel ports mapped in I/O space (Addresses shown in Fig. 1 are for LPT1:).

Port 378_{16}: this is the data output port. Bits 0-7 from the bus are latched and appear on the 25 way-connector, pins 2-9. The port can be read, but the three-state outputs from the latch are permanently enabled, so the port cannot be used bidirectionally. A series resistor and capacitor to ground on each of these lines is provided to reduce crosstalk in the printer interface cable.

Port 379_{16}: this is the status input port. Not all eight bits are used. The bit allocation and corresponding pin numbers on the connector are

Bit	Function	
$D_0 - D_2$	Not used	
D_3	$\overline{\text{ERROR}}$	pin 15
D_4	$\overline{\text{SLCT}}$ (on-line)	pin 17
D_5	PE	pin 12
D_6	ACK	pin 10
D_7	Busy	pin 11

Bit 7 is inverted from the connector to the bus. Bit 6 can double as an external interrupt (IRQ_7 on LPT1:).

Port $37A_{16}$: This port provides the output control signals. Again not all the bits are used.

Bit	Function	
D_0	STROBE	
D_1	AUTO FD XT	(enable auto-line -feed)
D_2	INIT	
D_3	SLCT IN	(printer enable)
D_4	Enable interrupt (IRQ_7)	1 = enabled)
D_5- D_7	Not used	

Bits 0, 1 and 3 are inverted as they appear on the connector. Only the STROBE signal has an output filter. Again, like the data port the outputs can be read back. The inversion of signals is corrected on a read to the bus.

PC PRINTER PORT CONNECTIONS

Signal allocations for the 25-way connectors are as follows:

Pin	Direction	"Centronics"	Signal
1	Out	$\overline{\text{STROBE}}$	
2-9	Out	Data bits 0-7	
10	In	$\overline{\text{ACK}}$	Acknowledge
11	In	BUSY	
12	In	PE	Out of paper
13	In	SLCT	Printer selected
14	Out	$\overline{\text{AUTO FD XT}}$	Auto line-feed
15	In	$\overline{\text{ERROR}}$	Error or off-line
16	Out	$\overline{\text{INIT}}$	Reset
17	Out	$\overline{\text{SLCT IN}}$	(to printer)
18-25	–	Common ground	

$\overline{\text{STROBE}}$: negative going pulse, clocks data into printer. Negative-going edge initiates data transfer. Data should be stable on both edges.
Data bits 0-7: full byte-wide parallel data path.
$\overline{\text{ACK}}$: negative-going pulse indicates that the printer has received strobed data. Pulse width is usually in the order of 10µs.
BUSY is asserted (high) during data transfer and will remain high when the printer is off-line. It is possible to use this signal as a handshake with polled printer driver software and to ignore acknowledge.
PE: a high indicates paper not detected; $\overline{\text{ERROR}}$ is usually asserted at the same time.
SLCT: active high indicates printer is present. May be just a resistor to the printer +5V power supply.
$\overline{\text{AUTO FD XT}}$: active low. When asserted the printer will automatically do a line feed following a carriage return.
$\overline{\text{ERROR}}$: the printer is in an error state if this signal is low. Taking the printer off line manually will also activate $\overline{\text{ERROR}}$.
$\overline{\text{SLCT IN}}$: input, active low, selects the printer. When high, data transfer will not take place. Some printers can be set to force the signal active internally.
$\overline{\text{INIT}}$: the printer is reset if this line is taken low. The printer is initialized on a cold boot of MS-DOS (ctrl+alt+delete). The Bios will also initialize the printer by sending a software reset escape code. This is valid for Epson and IBM-compatible printers.

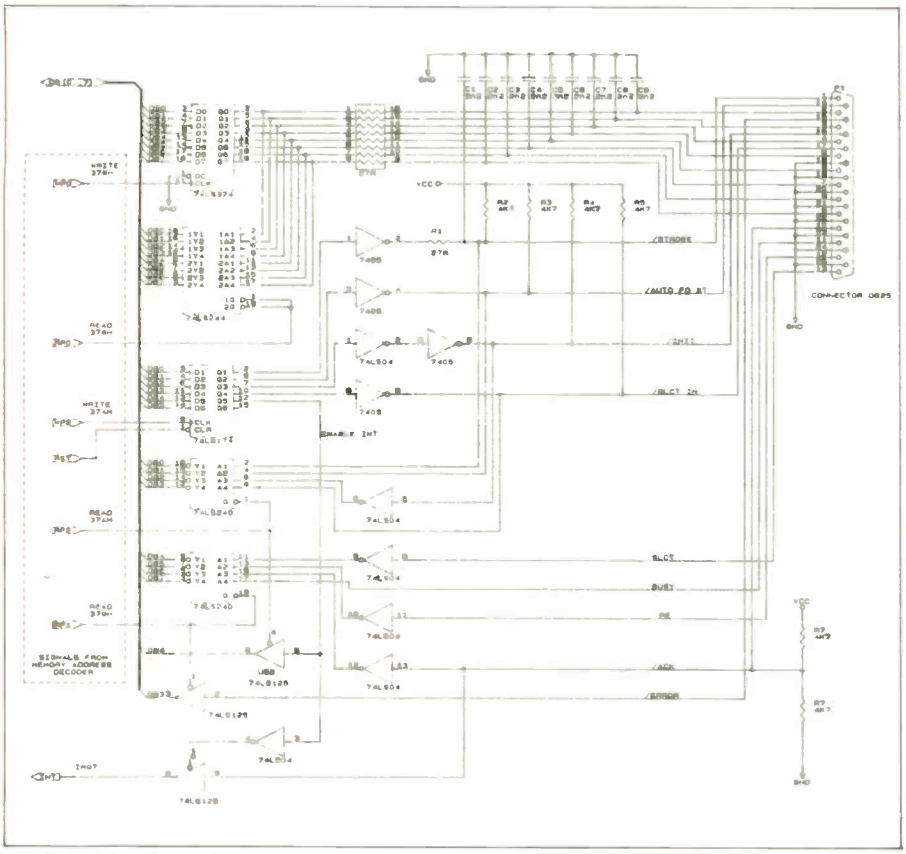


Fig. 1. LPT(n): interface to PC bus and 25-way connector.

to the port inputs. On each LPT(n): port found, this wiring can then be tested for. If the search software finds this combination on one port only, the port address has been located. One can see that with a little software ingenuity, the printer port could make quite a usable TTL I/O port.

Expansion

The limited number of inputs can be expanded using multiplexers. For example, with the addition of a single TTL 157 device, eight input and eight output bits can be provided. **Fig. 2** shows one connection method. The AUTO FD XT signal switches the 157 to select one of two sets of four inputs. These inputs appear in the upper four bits of the status port. The following software procedure (below) reads a byte for this hardware configuration. The XOR 88H instruction at the end corrects the sense of bits 3 and 7 which are inverted due to the inversion from the connector to the bus of the BUSY signal.

Signals from the port which would change rapidly in use with the printer are filtered (in the PC) to improve the line driving characteristics. The STROBE line is one of these. This must be taken

In total, twelve output and five input TTL lines available. MS-DOS can support up to three of these ports. The allocation of LPT(n): to any particular hardware port is a function of the Bios. For the PC/AT the base address of LPT1: is 378_{16}. Some documentation I have seen shows LPT1: to be $3BC_{16}$ although I have never encountered this in practice. Port addresses (in hexadecimal notation) are usually

	DATA	STATUS	CONTROL
LPT1:	378	379	37A
LPT2:	278	279	27A
LPT3:	3BC	3BD	3BE

If only one LPT(n): port is installed it is fairly simple to search all three possible addresses in software to find it. Since the data port at the base address is a read/write port, the simplest way of searching for the presence of hardware is to read and write complementary bit patterns to each of the possible data port addresses, checking that the write, and subsequent read, data bytes match.

If more than one port is installed, the software may require a dialogue with the user, to determine the correct port. An alternative is to wire, on the additional device, some of the outputs back

Listing 1: Software to switch LPT1 for parallel I/O use.

```
; Select phantom I/O
SLPHTM  PROC NEAR
        MOV DX,0378H        ;Data port address for LPT1:
        MOV AL,PHDAT        ;Get last data output to latch
        OUT DX,AL           ;Set up data on printer output port
        INC DX
        INC DX              ;DX points to control port
        IN AL,DX            ;Get current state
        MOV CTLST,AL        ;Save it
        MOV AL,00001110B    ;Pattern to select phantom I/O
        OUT DX,AL           ;Do selection
        RET
SLPTHM  ENDP

; Deselect the phantom I/O and select the printer
;SLPRN  PROC NEAR
        MOV DX,0387H        ;LPT data port address
        MOV AL,PHDAT        ;Get last data output to phantom
        OUT DX,AL           ;Set it up on LPT output
        INC DX
        INC DX              ;DX points to control port
        MOV AL,00001100B    ;Deselect bit pattern
        OUT DX,AL           ;Do deselection
        MOV AL,CTLST        ;Get control state
        OUT DX,AL           ;Restore printer control
        RET
SLPRN   ENDP

PHDAT   DB0                 ;Copy of phantom output latch
CTLST   DB0                 ;Control register state
```

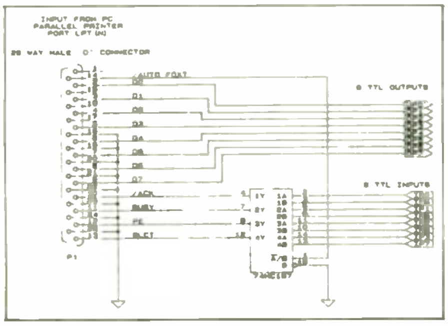


Fig. 2. Expanding inputs with a 157 device.

into account when writing interface software, particularly if long cables are to be used. In the above subroutine, comments show where it may be necessary to insert delays to allow time for signals to settle.

In practice, if the cable length is kept to a few inches and pull-ups used on all inputs, operation without delays is possible. If the software is to be used across a range of machines, then a subroutine call or macro which executes a series of dummy instructions could be placed at the delay points in the code. If the number of iterations of the delay loop is determined by a variable, set when the program is initialized, then performance can be either fine-tuned by hand or set following a processor speed calculation.

Immunity from crosstalk can be improved by using twisted pairs instead of the more convenient ribbon cables. Adding capacitors in the order of 1nF to those lines which are not filtered will improve noise immunity. This may prove essential on some fast machines if the lines are used as clocks. Finally, the use of high-speed c-mos devices in place of TTL will give a further improvement.

The simple circuit in Fig. 2 is practical only if a printer on this port is not required, or used so infrequently that changing cables is acceptable.

One of the lines to the printer, SLCT IN, is used as a device select. When this line is high the printer will not respond to data. By using it, the printer signals can be switched away from the printer to a "phantom" peripheral when the printer is de-selected by the computer.

Figure 3 shows a circuit to provide eight input/output lines with seven control signals maintaining a printer connection.

Some printers can be set to ignore the SLCT IN signal and be permanently on-line. This difficulty can be circumvented by gating the STROBE signal with SLCT IN, to force it high when the printer is de-selected by the computer. Both methods are used in Figure 3.

Buffer IC_1 isolates the printer cable load from the "phantom circuit"; its outputs are three-state, high impedance when the printer is de-selected. It is not essential.

IC_2 switches four of the status port lines to the printer when selected or to the "nibble mux" (IC_5) when not.

IC_3 is another quad two-input multiplexer, to switch the output printer control signals used by the phantom circuit. When the printer is selected, the STROBE and AUTO FD XT signals are switched to the output connector. In addition the clock to IC_4 is held low, maintaining the data in the latch, and SLCT IN is held low; SLCT IN is regenerated using a multiplexer in IC_3 to isolate it from the printer cable.

Latch IC_4 is used to hold the phantom output control signals when the printer is selected. Using a transparent latch in place of a D-type helps increase software speed. When SLCT IN and STROBE are high, the outputs from the printer port appear directly on the eight-bit phantom outputs. These bits can then be toggled by software as fast as if they were a direct parallel port from the PC bus.

IC_5 is a nibble multiplexer to expand four of the five inputs available on the LPT(n): interface to eight. The AUTO FD XT line is used to select the upper or lower four of eight inputs.

Buffer IC_6 provides eight outputs directly from the LPT output data. The three-state outputs are controlled by one bit from the "phantom" control latch. The data presented on the buffer outputs can be clocked using the same signal which controls the input nibble multiplexer.

The circuit can be used to emulate typical microprocessor control signals. Peripheral chips designed to interface directly to microprocessors could be connected in many cases without any additional control logic.

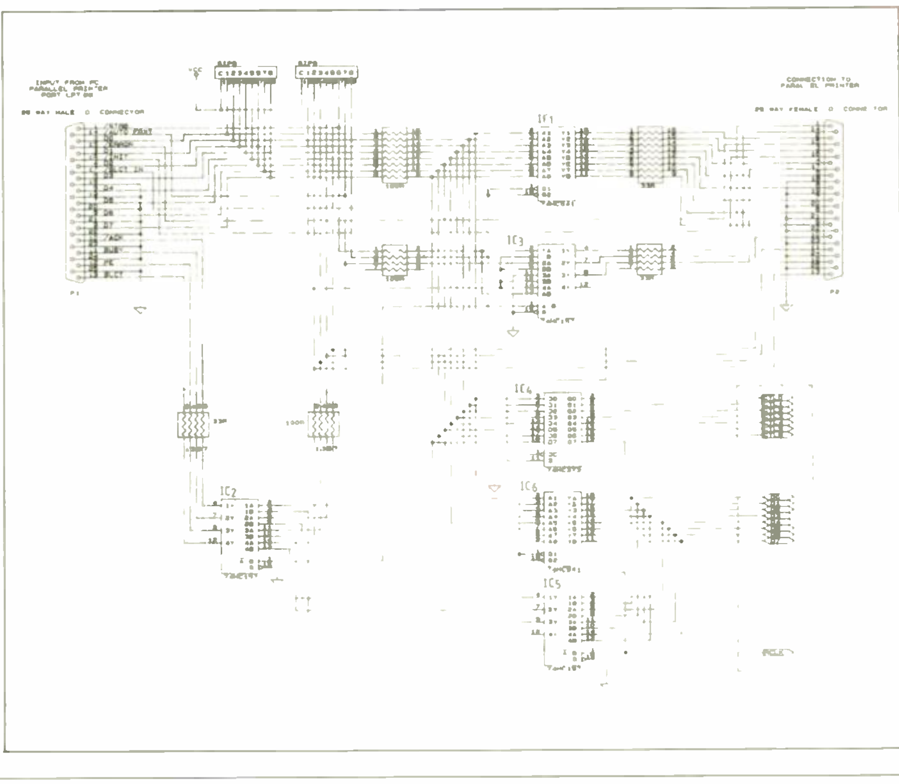
Control software

It is possible to use the eight I/O lines and drive the printer and phantom I/O alternately as if they were connected to separate ports. The only guaranteed un-crashable way of doing this is to write your own printer driver. Having said that, I have found that provided the output control port is restored to the same state as it was before the phantom port was accessed, the Bios printer routines are unaffected.

If complex printer drivers such as background spoolers are installed, it may be possible by careful control of the interrupts to use both printer and phantom device simultaneously.

Driving the output (phantom) control port is straightforward. First save the contents of the printer control latch, then set up the new phantom output state on the printer data port. A single write to the printer status port (with the

Fig. 3. Eight-bit bidirectional interface with control signals.



appropriate bit pattern) can de-select the printer and set the "phantom output" latch transparent. The printer data port can now be driven directly. When the printer is required, hold the current "phantom" latch data on the printer data port and restore the printer control port to its previous state.

Reading a byte from the phantom input is not quite as simple. The input port has to be selected by writing an appropriate bit pattern to the printer control port, after its current state has been saved. If the STROBE line is set low when the printer is de-selected, ideally the "phantom output" latch would be undisturbed. However, since in the normal state STROBE is high, it is possible that should the multiplexer control signal switch the multiplexer before STROBE becomes low, a glitch will appear on the clock to the ltch. Setting the latch inputs (via the printer data port) the same as the current latch state ensures that the latched data outputs will not change should this occur. Conversely, if the STROBE signal changes before the multiplexer control signal, the strobe to the printer may momentarily be active, causing a random character to be printed. This is less likely, since the STROBE signal is delayed slightly by the RC combination in the LPT(n) interface.

The safest method for both selection and de-selection is therefore to keep STROBE high, maintaining a copy of the "phantom" latch data on the printer data port outputs until the multiplexer outputs can be guaranteed to be stable; STROBE can then be taken low, freezing the "phantom" latch outputs.

Once selected, the procedure RDBYTE can be used to copy a byte from the phantom input port. If a single bit test is required, the routine can be simplified to read only the group of four bits containing the bit in question. The code extract (above, right) shows selection and de-selection for the circuit in Fig. 3.

The routines will not cause problems with the Bios printer routines if the printer control port is in an idle state when the SLPHTM procedure is called. This will be the case if the printer is driven by the application program via MS-DOS, or the Bios.

Before leaving phantom I/O and selecting the printer, the variable PHDAT must be updated with the current state of the "phantom" output latch.

Using a circuit such as this, I have developed an interface to the video frame store designed by Don Clarke, published in *Electronics & Wireless World* in 1987. The software, written in a combination of Forth and machine code, is able to send a 64Kbyte image to the frame store in less than 1.5 seconds and read it back in less than 2. (The PC used was a PC/AT-compatible Dell 200). In the slower, input direction, data transfer is still faster than 256K bit/s.

Listing 2: Data input routine. Data bytes are returned to register AH as two nibbles.

```
; Read two "nibbles" from LPT1: port and return a byte
; Call: none        Ret: byte in AH

RDBYTE  PROC NEAR
        MOV DX,037AH       ;Control port address
        IN AL,DX           ;Read control register state
        MOV CH,AL          ;Save register state
        MOV AL,00000111B   ;AUTO FD XT=low, no interrupts
        OUT DX,AL          ;Select lower byte
        DEC DX             ;Point to input port
        MOV CL,4           ;C set for shift 4X
; (Insert optional delay here)
        IN AL,DX           ;Read lower four bits
        SRL CL,AL          ;Shift to lower position in AL
        MOV AH,AL          ;and save in AH
        INC DX             ;back to control port
        MOV AL,00000101B   ;AUTO FD XT = high
        OUT AL,DX          ;Select upper four bits
        DEC DX             ;DX back to input port
; (Insert optional delay here)
        IN AL,DX           ;Read upper four bits
        AND OFOH           ;Mask lower bits
        OR AH,AL           ;Combine previous read, lower bits
        XOR AH,88H         ;Correct bit inversions
        MOV AL,CL          ;Get old control register state
        INC DX             ;DX points to control register
        OUT AL,DX          ;Control register restored
        RET                ;Ret: byte in AH
RDBYTE  ENDP

<end of listing 2>
```

Figure 4 shows a far simpler interface for an A-to-D converter, using a serial A-to-D chip, an ADC0831 by National Semiconductor, and a single 157 device. The ADC0831 is controlled by two signals, clock and chip select. Data is clocked out of the ADC0831 chip on the negative-going edge while chip select is low. The data out signal is the only output. The output format is a start bit (low) on the first clock followed by eight data bits, MSB first.

The 157 is used to switch an LPT(n): input line to the printer when SLCT IN is low and the converter when high. Chip select and clock are derived from two bits of the LPT(n): data port. Provided STROBE remains high, activity on this port is ignored by the printer. The converter input can be expanded to eight by adding an analogue multiplexer, such as a 4051, with the selection address derived from further LPT(n): data bits.

Possible applications are endless; and once the control software technique is mastered, the LPT(n): ports are as usable as a dedicated parallel I/O port. ■

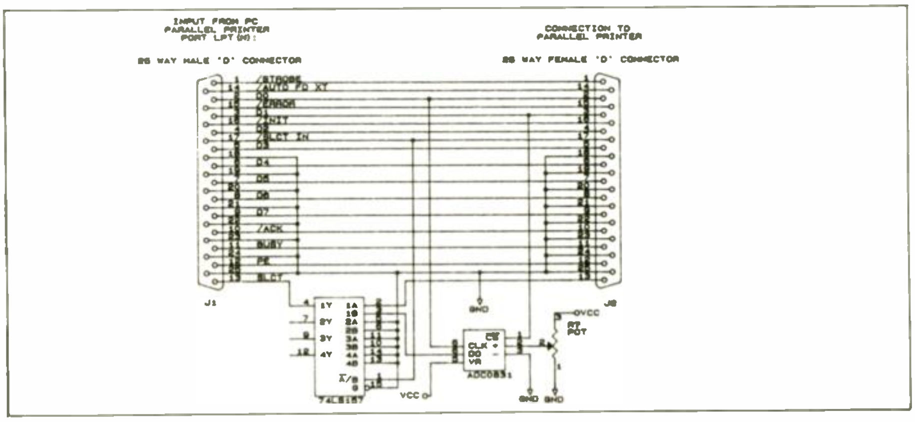


Fig. 4. Simple A-to-D converter.

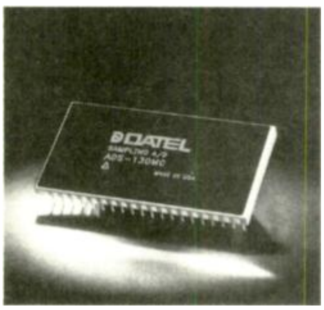
ACTIVE

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

Sample-and-hold amplifier. The AD1154 16-bit linear sample-and-hold amplifier gives ±0.00076% maximum gain non-linearity and an acquisition time of 3.5μs. It allows conversion of analogue-input signal bandwidths up to 32kHz at 16-bit accuracy and up to 128kHz at 14-bit accuracy. Analog Devices, 0932 253320.

High-speed c-mos A-to-D convertor. The Precision Monolithics ADC-912 is the industry's first low-noise, precision, 12-bit, high-speed, c-mos analogue-to-digital converter. It has a low-noise comparator that results in operation quieter than one-sixth of lower sideband. Conversion time is 12μs and access time is 90ns. Bourns Electronics, 0276 692392.

10MHz 12-bit sampling A-to-D converter. The ADS-130 hybrid device features a minimum throughput of 10MHz and converts signals up to the Nyquist frequency. It incorporates an internal sample-and-hold amplifier with a maximum slew rate of 250V/μs and acquisition time of 50ns maximum. Aperture uncertainty is 7ps. Datel, 0256 469085.



Display A-to-D converters. The Teledyne Semiconductor TSC822/TSC823 are analogue-to-digital converters incorporating LCD display drivers. They are for the low-power hand-held meter market and low-voltage battery operation. The TSC822 has 3999 counts maximum resolution, while the TSC823 provides 1999 counts maximum. Trident Microsystems, 0737 765900.

Development and evaluation

ADC evaluation. A sampling A-to-D converter board from Datel simplifies evaluation of the company's 10bit, 18MHz ADS-311 converter. The ADC-B311E is a Eurocard-size A-to-D converter board which incorporates the ADS-311 sampling A-to-D converter. It features a guaranteed sampling rate of 18MHz and a signal-to-noise ratio of 53dB at 5MHz. Datel UK, 0256 469085.

DSP. Ultra Digital Systems has launched a DSP target and prototyping board, based on the TMS320E15. The Eurocard device is designed to run the whole range of DSP programs, and also provides a prototyping area. The processor is the eprom version of the popular and successful TMS32010. The board has fast A-to-D and D-to-A converters, analogue and digital I/O lines and provision for input and output filters. Ultra Digital Systems, 051 708 9465.

Discrete active devices

Microwave fets. A family of high-power microwave GaAs fets by NEC has been developed for satellite communications systems, car telephone and similar applications. The NE345L family delivers up to 20W of output power at 2.3GHz. Two devices, NE345L-10B and NE345L-20B, are rated for power output of 40dBM (10W) and 43dBm (20W) respectively. NEC Electronics (UK), 0908 69133.

High-mu triode. The Siemens RS 3061 high-mu triode is rated at 100kW for continuous working and 200kW for pulse operation. Output power is twice that of the proven RS 3021/27/41 series of valves, which have ratings ranging from 10kW to 50kW for continuous working and up to 1000kW for pulse operation. The amplification factor is 100. Siemens, 0932 752323.

Interfaces

PC development tools. The PROTO-1 is a PC/AT bus prototyping board, which includes all the interface logic necessary to implement port-mapped cards. A selectable base address is provided, together with buffered data and address, with access to certain control lines. EXT 1 allows cards to be connected to the PC while remaining accessible. Blue Chip Technology, 0244 520222.

Frame grabber. The IMAGEWISE/PC real-time video digitizer and display board can digitize any NTSC, PAL, or Secam video frame to a resolution of 256×255 with 256 grey levels. The board provides composite video output and digitized pictures can also be shown on an EGA or VGA monitor. A digitized picture grabbed or software generated can be applied as a caption or mask on a live video signal. JB Designs & Technology, 0285 651822.

Linear integrated circuits

Operational amplifier. The OP-177 low-noise bipolar-input op-amp provides the performance of chopper-stabilized amplifiers without their problems of noise, limited common-mode input-voltage range, and the need for external storage capacitors. Offset voltage is 10μV maximum at room temperature and 20μV maximum over the full military temperature range. Offset voltage drift is 0.1μV/°C maximum. RR Electronics, 0234 270272.

Memory chips

8 Mbit static ram module. The MS81000RKX 8-megabit module, based on eight 128k × 8 surface-mount packages, offers a choice of access times from 70 to 150ns. Typical operating power is 140mW and standby power consumption is typically 66mW for the standard module or 80μW for the low-power device. Hybrid, 091 258 0690.

Opto electronic devices

Phototransistor. The TDET800 range of phototransistor detectors from Three Five Systems features six devices with different sensitivities from 0.5 to 15mA minimum light current for illumination levels of 5mW/cm². The range features an acceptance angle of ±20deg. Abacus Electronics, 0635 36222.

Optical distribution unit. The L3250 multi-interface distribution unit incorporates a power supply unit and up to ten communication cards for data and optical connection. Led status indicators display the type of interface in operation and the status of the communication link. All standard interfaces are supported. Belling Lee Intec, 01 367 0080.

Opto isolated RS232. Maximum MAX250/251 form a RS-232 dual transmitter/receiver pair. When combined with four 4N26 optocouplers, four capacitors, a diode and a small pot core transformer, it develops a complete 19.2kbaud dual isolated RS-232 transceiver. When higher speed optocouplers are used, such as the 6N136, a 90kbaud rate can be achieved. Kudos Thame, 0734 351010.

Oscillators and crystals

Surface-mount crystal. With a maximum height of 3mm and a width of 8mm, the MC1000X microprocessor crystal is available in a frequency range of 8 to 60 MHz. The crystal has an adjustment tolerance of ±50ppm at 25°C and a temperature tolerance of ±50ppm over −10 to +60°C. Typical Q factor is 100,000. Total Frequency Control, 0903 745513.

PASSIVE EQUIPMENT

Connectors and cabling

Adapter sockets. Sockets which accept devices on a 0.4in (10.16mm) pitch can be used on boards with dip holes on a 0.3in (7.62mm) pitch using the Aries adapter socket. The sockets are available in sizes from 10 to 22 pins. Aries Electronics (Europe), 0908 260007.

Optical-fibre underwater cable. This cable has been designed to meet the special requirements for operation in tidal flats and coastal waters. Hayden Laboratories, 0753 888447.

Mass termination Belden cable. Belden unshielded MASS-TER cable offers both round and flat cable under one jacket. It combines the ease of termination of Vari-Twist flat cable with the flexibility and air-flow enhancements of round cable. MASS-TER is PVC jacketted in a round construction of pre-insulated twisted pairs, with 2in flat terminating sections spaced at 20in intervals. Wadsworth Electronics, 01 941 4716.

Displays

LCD graphics modules. The Epson EG series of high-contrast graphics LCDs are compact alternatives to LCDs and CRTs for the portrayal of graphics. The EG series uses either Super TN technology or Epson's black-on-white NTN technology. The complete range incorporates the Epson E1330 LCD controller. Selected models use 'chip on flex' technology, where each LCD driver is mounted directly onto a flexible PCB. Hawke Components Distribution, 01 979 7799.

Colour monitor. The 14in autotracking colour monitor (FA3415ATKE) from Mitsubishi automatically scans all horizontal frequencies between 15.7 and 35.5kHz and all vertical frequencies between 50 and 87Hz and is compatible with IBM PC/AT, XT and PS/2 and Apple Mac II. It is suitable for CGA, EGA, PGC, MCGA and VGA applications. RR Electronics, 0234 270272.

LCD flow status indicator. A solid-state LCD flow status indicator by Racal Microelectronic Systems, the FSI, is a 15V, dye-phase-change LCD device, housed in a 1in square plastic casing. The face is a red or black LCD showing a horizontal or vertical strip, whose orientation is switchable according to whether or not current is flowing. Racal Microelectronic Systems, 0734 782158.

LCD controller/driver. The Sanyo LC7985 is a single-chip LCD controller/driver incorporating a character generator and user-definable character ram. It is pin compatible with the HD44780 and supports multiple-line and multiple-column displays, with the addition of the LC7930N matrix driver. Techmost Electronics, 0279 652444.

Filters

FIR filters. L64260 and L64261 programmable high-speed finite impulse response filter devices are capable of processing at data rates up to 40MHz with full 16-bit data and coefficients. Each device consists of four 16-bit multiplier-accumulator elements, each having four data and four coefficient registers. Operands for each element can be register or off-chip selected. Separate input buses supply data and coefficients for each of the four elements. LSI Logic Europe, 0344 426544.

Instrumentation

Pressure meter. The model 94 3½-digit pressure meter is supplied either complete with a matched pressure transducer or as the basic meter for use with a user-supplied pressure transducer. Analogue input characteristics include common-mode rejection of 80dB maximum; input voltage of −10 to −15V, and bias current of 10nA. Amplicon Liveline, 0273 570220.

Dual channel data analyser. The Microlog 6220 by Palomar is the first portable data analyser to feature dual-channel operation. The instrument is designed for recording and analysing data from transducers used on rotating machinery. It features a high-contrast LCD panel and the dual-channel facility allows the operator to observe x-y orbit measurements. Endevco UK, 0763 261311.

Digital oscilloscope. The VP-5742A from Panasonic offers high-speed sampling at 100MHz and 8-bit resolution. It can be used as a dual-trace 100MHz oscilloscope but, as a DSO, it operates from DC to 35MHz and offers two modes: repetitive – where high-speed signals are reconstituted from memory for high-accuracy presentation, and roll – for measuring low-speed signals in real time. GPIB interface is standard. Farnell International, 0937 61961.

Frequency counter. The GRC-8130G is a microprocessor-controlled frequency counter which offers a frequency range from DC to 1.3GHz. Two channels are provided to cover the range. Resolution remains high at both high and low frequencies. A self-diagnostic routine maintains reliability. Flight Electronics, 0703 227721.

Mains monitor. The ONEGraph mains monitor prints out normal-mode and common-mode noise voltage graphs. It also prints out complete AC voltage disturbance information, including time of day, duration and a graph showing the degree of voltage deviation from the nominal. There is a choice of 8-hour or 6-day time scales with noise ranges 0 to 6000V. ONEAC, 0235 34721.

Oscilloscopes. Two low-cost dual-channel oscilloscopes are intended for education and servicing. The PM3208 is a 20MHz model, whilst the PM3209 has a bandwidth of 40MHz and offers delayed-timebase facility. A variable hold-off is provided, as is an x-y mode. For high-accuracy measurements, the output of channel A can be connected to a frequency counter or similar equipment. Philips Scientific, 0223 358866.

Stereo test set. The Dorrough model 1200 stereo signal test set includes a pair of loudness monitors, each of which indicates both peak and average levels on a single display. Measurement range is 96dB (−76 to +20). The meters indicate level, balance, crosstalk and signal-to-noise ratio over the entire range of a system, from noise floor to clipping. Plasmec Systems, 0252 721236.

Energy analyser. Elcomponent's MICROVIP Mk1.2 is designed to analyse single and 3-phase low voltage (500V) systems and includes a 9-page enhanced LCD display and an integral printer to provide hard-copy readout of voltage, current, power factor, average power, kW, kWh, kVArh, kVAr and operating period. RS Components, 0536 201234.

Scalar network analyser. The ZAM 52 performs direct measurements on VSWR, return loss and insertion loss, with a dynamic range of 96dB and 2.5GHz and 71dB at 18GHz. It has a resolution of 0.001dB and a measurement uncertainty of 0.2dB. Rohde & Schwarz UK, 0252 811377.

Literature

Optoelectronics and power semiconductors. The Optek catalogue provides data on a range of power-switching transistors, fast and extra-fast-recovery rectifiers and LVA zener diodes, most of which are packaged for surface-mount applications. Other devices are optically-coupled TO5 isolators and four-channel low-input current optocouplers. MCP Electronics, 0734 772345.

Relay manual. The relay manual from Schrack contains almost 90 pages of information about their complete range of relays, sockets, timers and I/O modules. In addition to the technical and physical data given, the manual contains application notes, relay definitions, a glossary and a guide to quality assessment. Schrack, 01 868 1211.

Production equipment

Room ionization. A retro-fittable room ionization system, the NilStat, reduces the problem of electrostatic discharge in sensitive work areas. By flooding the area with sequentially balanced quantities of ions, the system provides a balanced ionized atmosphere. Dage (GB), 0296 393200

Soldering iron thermometer. This indicates soldering bit temperatures on a clear 12.5mm liquid-crystal display. The thermometer indicates temperatures up to 500°C with a resolution and accuracy of 1°C ETI, 0903 202151

Flux controller. A programmable flux controller for wave-soldering machines, the series 4500 from Electronics Controls Design, features a low-solids sensor designed to cope with close tolerances between the specific gravity of flux and thinners, and is accurate to ±0.001. Low detection limit is 0.75 and high detection limit is greater than 1.00. Hollis Europe, 0634 716733

Cable cutter. Bench-mounted cable cutter, the model HC10, has two hardened tool steel guillotine-style blades which shear most wires and cables up to 25.5mm in diameter, dependent on construction, and solid copper conductors up to 4AWG may be easily cut. A protective guard slide is provided. Rush Wire Strippers, 0264 51347

Dip-soldering unit. Soldermatic has introduced a unit for use in soldering ceramic lead frames and other electronic, electrical or small mechanical components. The unit consists of a rectangular steel bench with, inset, a stainless-steel fluxer and a rectangular solder pot, with a motor and impeller system, which produces a flowing solder wave. Soldermatic Equipment, 01 689 0574

Power supplies

DC-DC converters. With a minimum efficiency of 75%, the TM series of converters from Computer Products Power Conversion maintains full output power to an ambient temperature of 70°C and units operate from a 24VDC or 48VDC line with 2:1 input-voltage range. Load stabilization is 1% and line regulation 0.5%. Computer Products Power Conversion, 0234 273838.

Bench power supplies. Units from Flight Electronics offer fully floating outputs and all models have push-button mode selection. The units have meters, led or LCD displays. Outputs are 0-18V at up to 30A, 0-30V at up to 10A and 0-60V at up to 3A; multiple units are available. Flight Electronics, 0703 227721

Switching regulators. The 3T series of DC-DC switching regulators provides up to 360 watts of regulated DC power for less than £50. Operating from a DC input of between 10 and 60V, these modules have an adjustable output from 4.5 to 30V at up to 20A. Negative outputs of up to 5A are also catered for. Line and load regulation is less than 1%, ripple and noise typically 150mV pk-pk. XP, 0734 572611

40W SMPS. The ZPS-40 40V switched-mode power supply is a 40W triple-output unit suitable for small systems. It has approvals to international safety and emission standards of VDE 0806, VDE 0871/B and IEC 380. The unit provides outputs of 5.0V, 2.5A as well as +12.0V, 2.02A and −12.0V, 0.10A. Zenith Electronics (Ireland), 0306 76730

Production test equipment

Wafer measurement system. The ADE wafer measurement system offers an increase in resolution down to 10nm and a repeatability of 15nm, enabling the model 8300 Microscan to be used to check wafers ranging from 3in to 150mm for up to 21 sort parameters. It directly supports the proposed SEMI flatness decision tree specifications. Intertrade Scientific Ltd, 0908 676633.

Programmers

Emulation and programming for 8752. The 8052 family MICE25/8052 in-circuit emulator from ARS Microsystems offers programming and verification on microcontrollers including the Intel 87C252, 87C51FA, 87C52, 8751, 8744 and AMD 8753H and 9761H at a speed of 16MHz in emulation. Also supported are device selection checking, memory read/search, programming/verification tests and memory checksum. ARS, 0276 685005.

Logic programmer for PLDs. The model 860 will program, without an adaptor, the majority of the standard PLDs from the major manufacturers, in 20, 24, 28 and 40-pin dip packages. Socket modules are available to program 20, 28, 32, 44, and 68-pin PLCC devices. Microtel Systems, 0784 439881.

Switches and relays

Solid-state relays. Dual solid-state relays are available in both 25A and 40A versions and use inverse-parallel SCR output design with integral dv/dt snubber circuitry to provide protection against false triggering. 20A quad SSRs incorporate four independent AC triac relays in a single panel-mount package. Crydom UK, 0883 717250.

Miniature lockswitch. A two-position, key-operated switch projecting less than 30mm behind an equipment panel, the series SRL lockswitch is available in two styles – single pole with 90° indexing and double pole with 60° indexing. The contact rating of the switch module is 5A at 115V AC or 3A at 50V DC. Lorlin Electronics, 0903 725121

Transducers and sensors

Strain gauge conditioner. Analog Devices has introduced the 5B38 strain gauge conditioner with all the functions needed to excite a 300Ω to 10,000Ω gauge and produced a filtered, −5 to +5 V output at 10kHz bandwidth. Typical input and output offsets are 1µV and 40µV/°C respectively, with gain drift of ±25ppm/°C of reading. Analog Devices, 0732 253320

Pressure sensor. The model 84 stainless-steel pressure sensor developed by IC Sensors is offered in gauge and sealed-gauge ranges from 0-5 and 0-300psi and absolute ranges from 0-5 to 0-50psi, with an accuracy of ±0.5%. Eurosensor, 01-405 6060.

Vision systems

Integrated vision system. In the Heber integrated vision system IVS-20, all the vision capture, imaging analysis and data processing functions are carried out by the single unit, no PC or host computer or separate power supplies are needed. It has four video inputs and two framestores which are software selectable. Heber Data Systems, 0453 886647

COMPUTER

Computer board-level products

Memory upgrade for PS/2. Designed for the complete range of IBM PS/2 systems and compatibles, memory upgrade boards and expansion cards from Datrontech contain 1 or 2Mbyte of memory, comprising 80 or 100ns ram devices. The products are compatible with IBM PS/2 model 30/286, 50Z, 60, 70 and 80. Datrontech, 0252 723430.

Mass storage devices

Solid-state mass storage. The NEC µPD42601 Silicon File Memory, is a true "semiconductor disk" replacement for relatively slow and vulnerable magnetic disk drives. This 1Mbit c-mos device combines the low power consumption of a static ram with the large capacity and packing density of a dynamic ram. In normal mode (RFSH high), the µPD42601 is driven in the same way as a standard d-ram. The row and column access times are specified as 600 and 100ns, respectively. 2001 Electronic Components, 0483 742001.

Optical drives. The Pioneer DD-S5001 worm (write once, read multiple) optical disk drive provides 650Mbyte per removable cartridge of long-term storage for computer systems. The drive operates under DOS 3.3 and higher versions. PC/LAN, Novell NetWare, 10Net and 3Com3+ network operating systems are supported. The DD-S5001 is equipped with a SCSI interface as standard, optionally with a IBM-specialized SCSI. HTEC, 0703 581555

Software

Design and engineering. PADS-Designer/Engineer suites of software, described in a brochure from Microtel Systems, offers a complete solution to the majority of cad engineering needs or, in the case of PADS-Designer, a low-cost, high-performance PCB layout system. the full PADS environment includes PADS-Engineer, PADS-Designer, PADS-Route, PADS-CAE, PADS-Superouter, PADS-Plot, PADS-Drill, PADS-Conv and PADS-DXF. Microtel Systems, 0784 439881

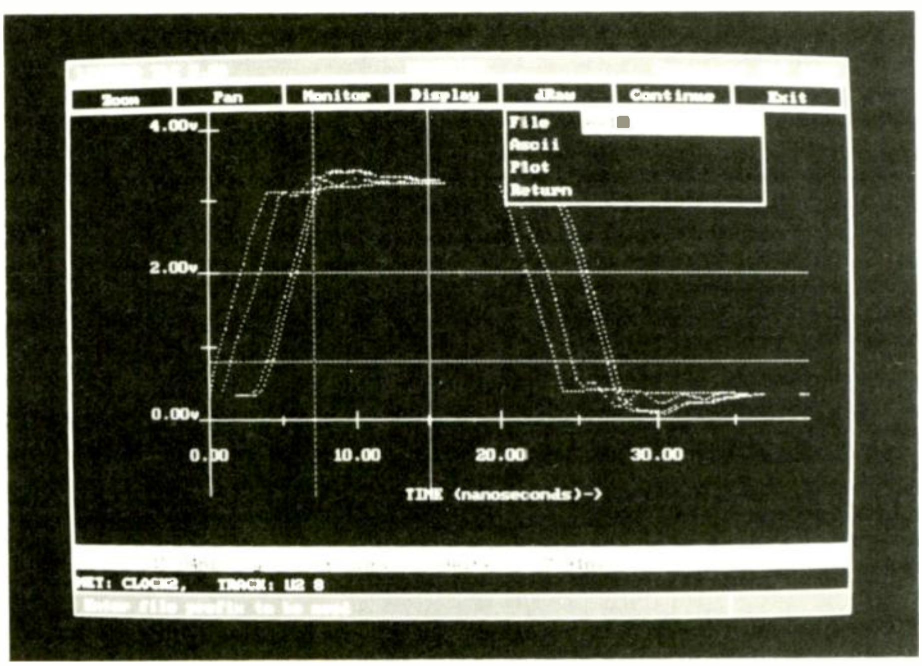
Transmission line calculator. The TLC allows digital designers to display the effects of network loading and printing-circuit board routeing. It calculates and displays the effects of transmission-line phenomena on digital signals. Designers can find the effects of incident and reflected signals, false clocks and degraded signals. ARS Microsystems, 0276 685005

Mathcad. MathCAD version 2.5, for IBM PCs and compatibles, features three-dimensional plots, output to PostScript printers, including the Apple LaserWriter, and importing of HPGL files from other graphics and cad packages. It also incorporates block cut-and-paste of multiple regions, improved accuracy of numeric solutions and matrix sort functions. Adept Scientific, 0462 480055

OS/2 for data acquisition. Wokingham UK OS/2 software support is available for the DT2901 and DT2905 simultaneous analogue input and analogue output data-acquisition boards for IBM PS/2 computers. Labtech Notebook (for scientific data acquisition) and LT/Control (for industrial process control) deliver control and analysis functions, a convenient menu-driven interface, and complete control of all DT2901 and DT2905 functions. Data Translation, 0734 793838

PCB design. PADS-Bronze, PADS-Silver and PADS-Gold ranges of PC-based CAE/CAD systems incorporate version 3.12 of the PADS design software. PADS-Bronze is an entry-level package that enables the user to design PCBs with up to 30 layers and 400 14-pin ICs. Silver offers all Bronze features and front-end logic capture. Gold provides a complete package for PCB design, including 100% routeing, whilst the user is performing other design tasks. Export Software, 0242 222307

Cad tools. Silicon Builder is an asic design optimization system that works at the chip level to automatically produce physical block layouts. It contains datapath and block compilers. Used with LSI Logic's silicon integrator toolset, Design Builder implements asic designs, offering chip partitioning and die size estimation; synthesis of finite state and register transfer machines; and automatic memory cell compilation. LSI Logic, 0344 426544.



CIRCLE NO. 106 ON REPLY CARD

CIRCLE NO. 156 ON REPLY CARD

CIRCLE NO. 134 ON REPLY CARD

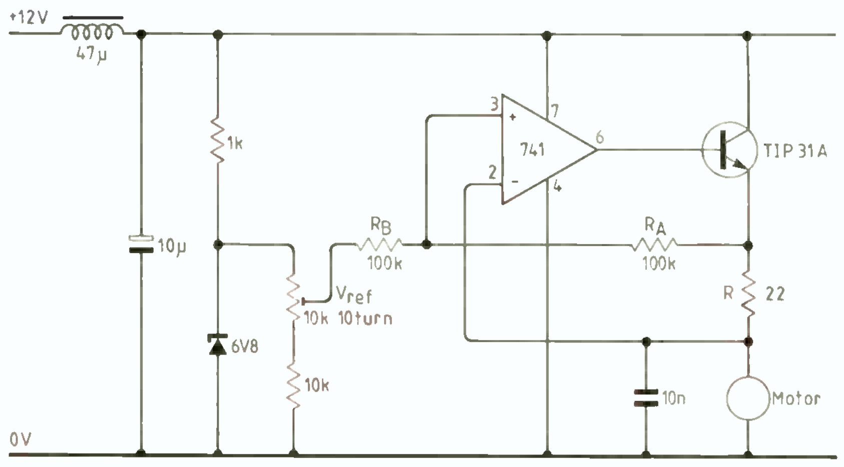
Constant-EMF cassette motor controller

Recently the capstan motor of my hi-fi cassette player started to produce unacceptable wow and flutter. Since the player is no longer made, and parts are not available, I first dosed the brushes with cleaning fluid in an unsuccessful attempt to cure the problem. Replacing the unit's rather crude motor regulator with the one shown however did restore correct operation.

Constant EMF is provided by the circuit. Since back EMF of a motor is directly related to shaft speed, constant EMF implies constant rotation speed.

Resistor R must have the same value as the DC resistance of the motor, which must be measured with the motor stationary. My unit measured 22Ω and when running at correct speed, the motor takes about 50mA, dropping 1.1V across its DC resistance and producing 4.4V as back EMF. Terminal voltage is 5.5V.

Voltage dropped across the 22Ω resistor is the same as that across the motor's coil. Owing to the virtual earth at the op-amp's input, the same voltage is dropped across R_A. Current through the resistor flows through R_B which has the same value as R_A, so the voltage at the bottom of R_B must be the same as the voltage applied to the motor. Since this voltage can be controlled by the 10-turn potentiometer, there is direct control of motor EMF regardless, within reason, of torque required to pull the tape.



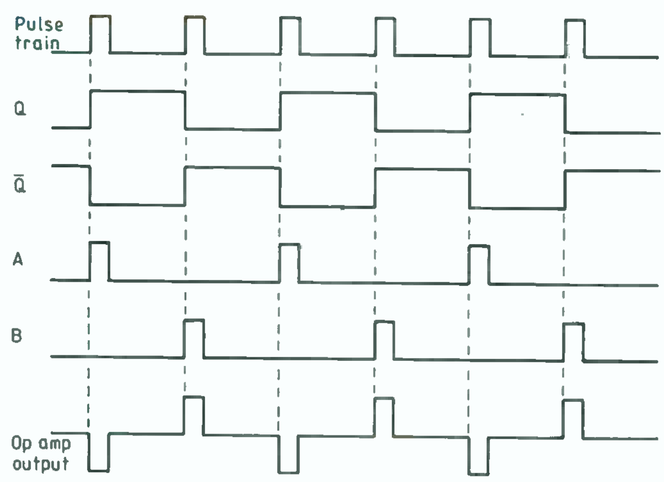
D.J. Greaves
St. John's College
Cambridge

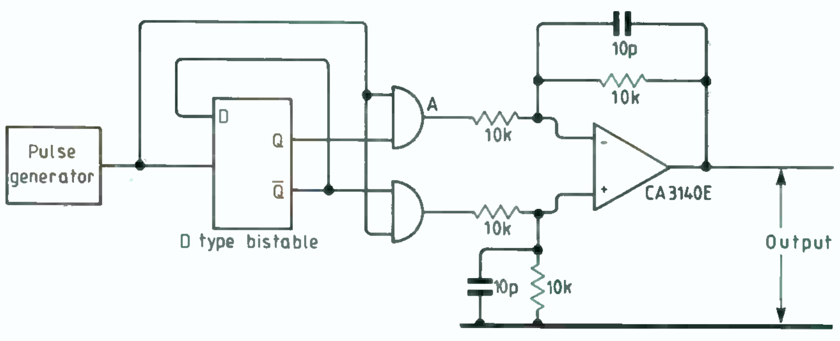
Unipolar-to-bipolar pulse converter

Usually, pulse generators produce unipolar pulses of either positive or negative polarity but it is sometimes useful to have alternate positive and negative-going pulses. Such pulses are needed, for example, when driving a liquid-crystal display.

This circuit converts a unipolar pulse train into a symmetrical bipolar train. Input pulses determine the pulse width and repetition frequency. They trigger an edge-triggered bistable IC whose two outputs feed separate AND gates. The other AND gate inputs are fed by the input pulse train. As a result, alternate unipolar pulses are produced for feeding the op-amp.

K.N. Rauniar
Umist
Manchester





Tuneable loudness control

In Liao's circuit in the June issue there were two small errors in the equations. Corrected, the equations read,

$$A=(R_1/2)R_2-1/4\pi^2f^2C_1C_2$$

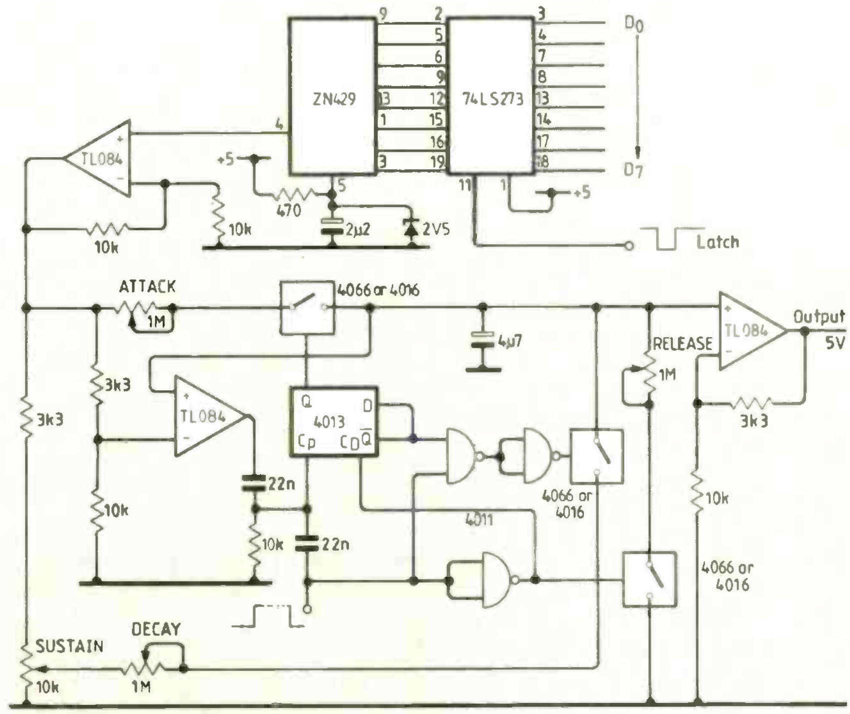
$$V_o/V_i=20\log[nR_1(A^2+B^2)^{1/2}/(C^2+D^2)^{1/2}]$$

Touch-sensitive synthesizer

In a touch sensitive synthesizer, amplitude of the envelope is proportional to how hard the key is pressed. In this circuit this quantity can be represented as a digital quantity or an analogue one applied to point A.

A c-mos-compatible input pulse is required to trigger the unit and its length determines the sustain time. Four potentiometers set attack, decay, sustain, and release levels; using component values shown, maximum output is +5V.

Edward Barrow
Powys
Wales



Triangle-to-sine wave converter

Having no reactive components, this simple and inexpensive triangle-to-sinewave converter is frequency-independent. With source and gate tied together, low-power mosfets have both a smooth characteristic and the proper nonlinearity for the feedback path of the op-amp.

Triangular waveforms are composed of odd multiples of fundamental sinusoidal frequencies. A low-pass filter removes the higher-order components to yield sinusoidal waveform at the fundamental frequency, but if constant output amplitude and phase relationships over a wide frequency range are required, the filter must be returned for optimum response each time the input frequency is changed.

An unconventional solution to this problem uses an op-amp with mosfets in its feedback path. Feedback is usually via a diode, but the op-amp accentuates the diode's breakpoints and produces an undesirable linear output.

While several types of fets are acceptable, a P-channel BSS110 works well in this circuit. Two parallel connected fets with opposite polarity in the feedback path of IC_1 promote shaping on both the positive and negative portions of the input waveform.

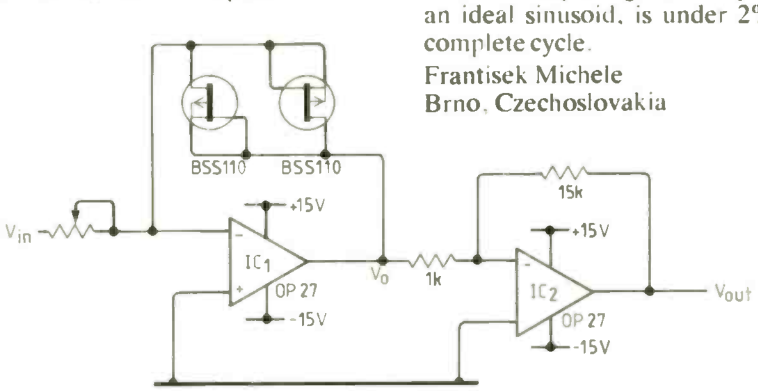
Note that only one fet at a time is forward biased; the reverse-biased fet behaves like a large resistance in parallel with it.

Input current V_{IN}/R_1 is adjusted to allow a level of current that pushes the fets just into their nonlinear knee.

Because V_o equals V_{DS}, output response is determined by the active fet's VA characteristic. To achieve a sinusoidal output, the amplitude of the input voltage waveform must be adjusted to provide the proper amount of drive to the wave-shaper circuit.

Accuracy is determined by the adjustment of R_1 and the symmetry of the input waveform about 0V. Average error of output signal, compared with an ideal sinusoid, is under 2% over a complete cycle.

Frantisek Michele
Brno, Czechoslovakia

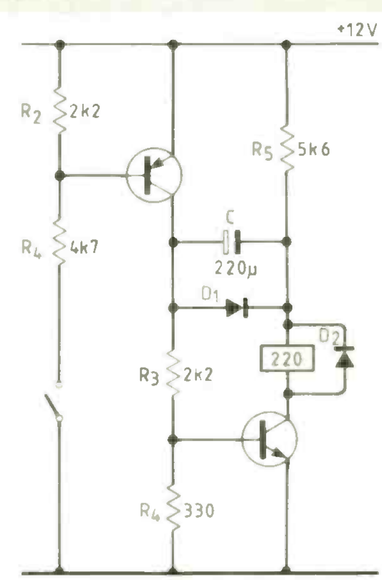


Battery-saving relay control

Most relays stay on with coil currents below half of the rated value, i.e. at a quarter of the rated power. This circuit provides a voltage surge to turn the relay on and after that a lower holding voltage.

A minimum delay of $3C(R_4+R_5)$ – about 5s with the components shown – must be allowed between power on and relay switch on; the same delay must be allowed between relay operations.

Jean-Claude Baumeister
Chantraine
France



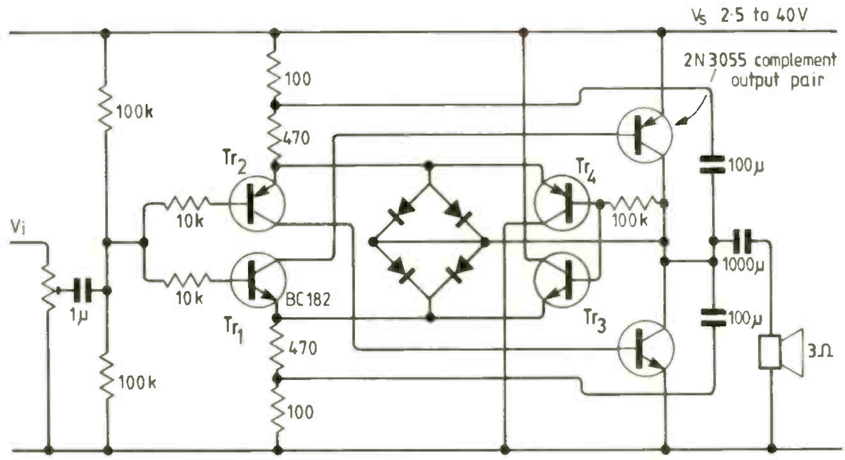
Sampling audio mixer

This circuit uses a different approach to mixing audio signals. Instead of taking the usual continuous sum of all the signals, it samples each signal at approximately 40kHz in a sequential order. The bonus of this is a better signal-to-noise ratio since only one of the mixing resistors is switched on at any one time.

Because it is not a continuous sum, the volume of each input can be set with greater independence of the other two inputs. Each counter output runs at about 40kHz.

When mixed, the signals feed a second-order low-pass filter with a 3dB point of approximtely 10kHz to filter out the sampling frequency. The system can be expanded for up to ten inputs by moving the reset input to the next unused output of the decade counter. The clock should run at N×40kHz where N is the number of channels to be mixed.

Darren Yates
French's Forest
New South Wales



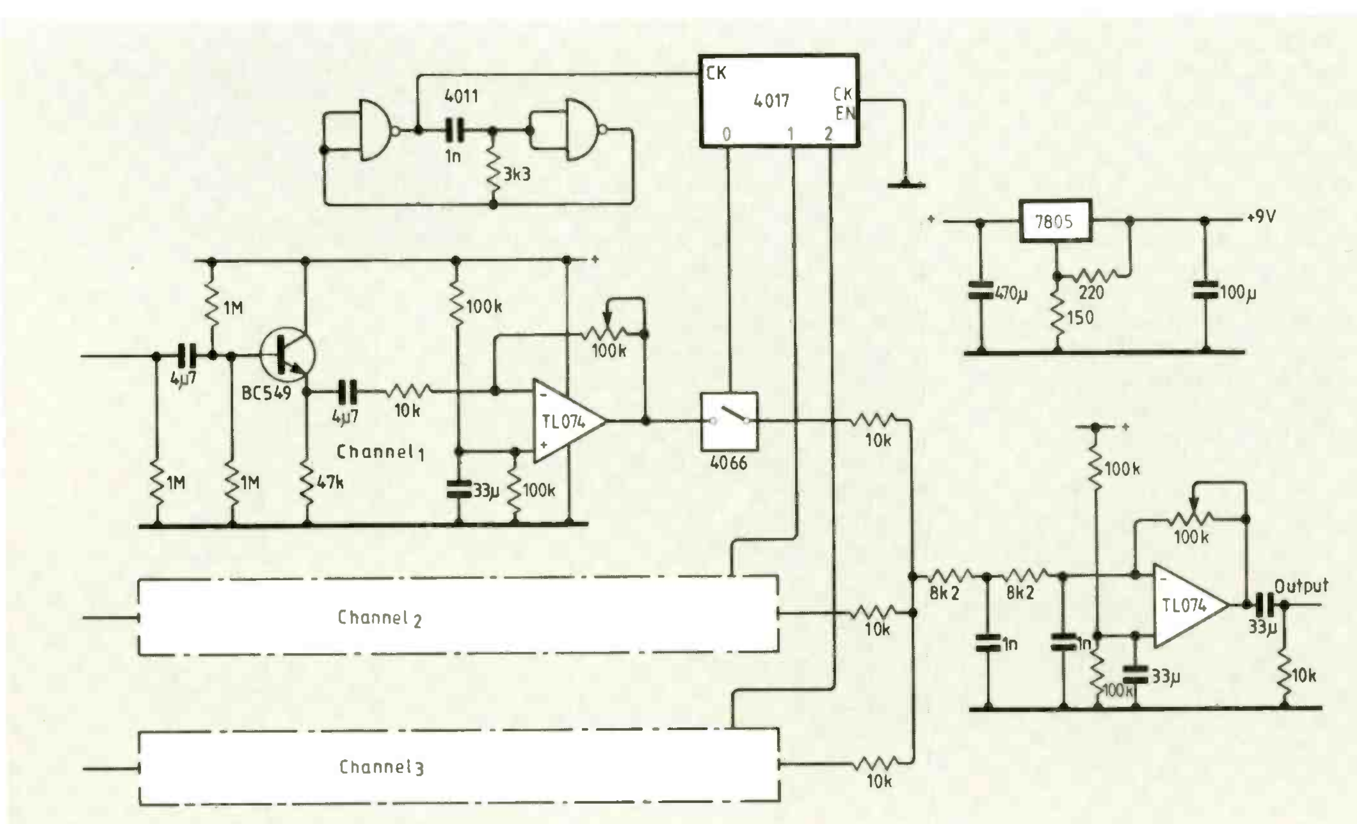
Symmetrical power amplifier

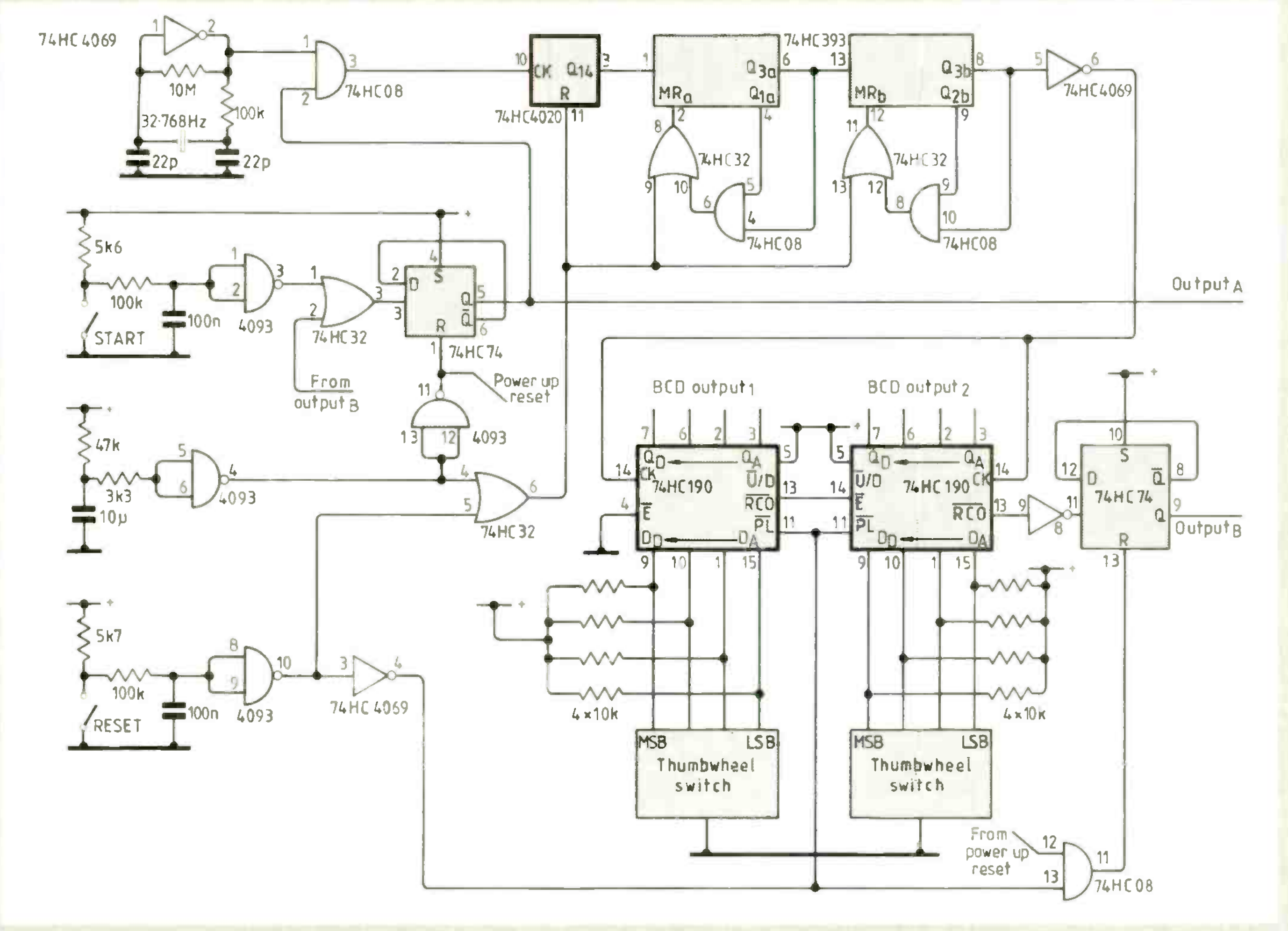
I have built and tested several versions of a symmetrical power amplifier; one is included above.

Cross-over voltage is controlled by the emitter-base turn on of the feedback sensors, $Tr_{3,4}$. The buffer provides adequate linearity for very low supply voltages of 2.5V and drives a 3Ω speaker or filament lamp. For higher supply voltages the quiescent current in the output pair rises rapidly so cross-over voltage is reduced further by high current cross section diodes from a 2A bridge rectifier. ($I_q \simeq 17$mA at 6V supply).

Without the diode bridge connected the "buffer" gives slightly greater than unity voltage gain because of the 100kΩ lever to the feedback sensor node.

P.J. Ratcliffe
Stevenage
Hertfordshire





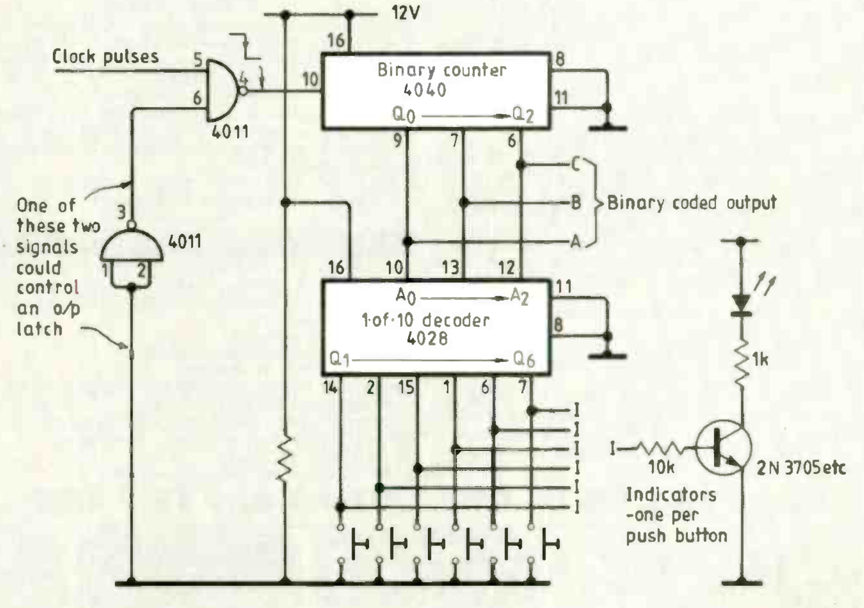
Precise minute counter

When timing a precise number of minutes, the required count is set up on complemented-output BCB thumbwheel switches. Two outputs are available, one which goes high for the duration of the count (output A) and one which goes high at the end of the count (output B).

Push switches start and reset the count.

S A Young
Bradford

Binary switch encoder



In my application, data from this binary push-button encoder was latched by other circuits but you could add an independent latch controlled either by the falling edge at pin 3 of the 4011 or the rising edge at pin 1.

F. Miners
University of Exeter

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MONITORS

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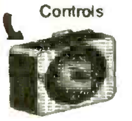
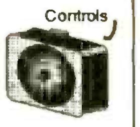


Microwave Speech / Data Links



Made for the US military to the highest possible spec, these units were originally designed as a highly rugged portable point to point distance measuring set. Inbuilt in the unit is a full duplex speech link which may be used as is, or adapted for use as a data link. Many features include **50 km point to point range**, approx 10.5 GHz operation for **max security**, low power consumption (typ. 2 amps at 12 vdc), and small physical size 14w, 15h x 13d **including built in dish**, fully portable weatherproof case. Supplied in used but tested condition complete with instructions and accessories.

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CIRCLE NO. 152 ON REPLY CARD

Silicon voice recorder

Cheap LSI, low cost d-ram and not much else can replace a tape recorder in applications requiring less than two minutes of spoken speech. Phillipe Clement of TI explains.

Voice recording and playback has become an increasingly commonplace feature of electronic systems such as telephone-answering machines, domestic 'talking message pads', security and entry-phone systems, advertising and educational toys. All have one thing in common – the need to record a relatively short spoken message, store it and play it back when required.

Older systems based on miniature tape recorders are being supplanted by all-electronic systems where the speech is converted to digital signals, stored in solid-state memory, then played back through a D-to-A converter and loudspeaker. Now all the required functions have been incorporated into a single chip which can be used in either simple devices or in extensive microprocessor systems. The Texas Instruments TMS3477 is such a device.

Any voice can be recorded – there is no need for advanced synthetic speech – and system development is rapid, since hardware and software requirements are low.

Requirements

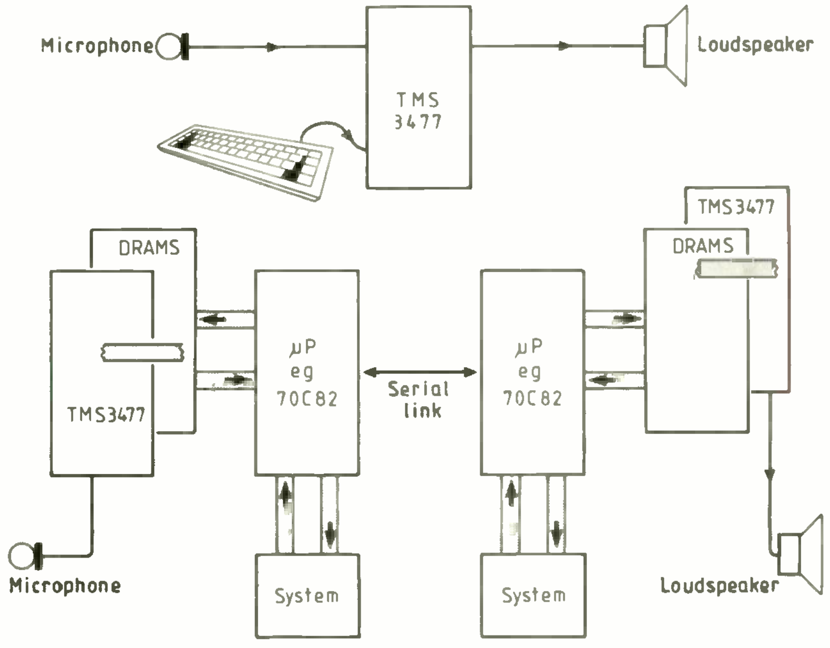
Three fundamental criteria have been met. Firstly, the system should provide good quality reproduction, preferably with facilities to choose a sampling rate – and therefore quality – appropriate to the application. TI based it devices on continuously variable slope delta modulation (CVSD) techniques, combined with the ability to select 16kHz, 32kHz or 64kHz clocks.

Secondly, performance-versus-cost considerations demand a speaker output from a 10-bit D-to-A converter with a typical 64kHz over-sampling clock and the device needs some means of suppressing the resultant over-sampling carrier noise.

Finally, consideration must be given to the way in which such a device connects with the memory ICs – standard d-rams for maximum cost-effectiveness – which will store the digitally-encoded message. The best method is a direct pin-to-pin connection, enhanced in this case by incorporating memory refresh counters on the chip.

Operation

In its simplest form, the recorder consists of a TMS3477 chip, microphone, speaker, keypad and d-ram. Four basic commands from the keypad mimic fundamental tape-recorder functions of record, playback, pause, and stop. Furthermore, because all the required commands, processing algorithms and memory-handling facilities are already



The speech chip incorporates a flexible bus for microprocessor interface but it can be used without a micro providing up to two minutes of recorded speech.

on chip, there is no need for masking, which makes for rapid product development without the constraints of volume production.

When REC is activated, the encoded bit stream is stored in internal d-rams via the DATA pin. Analogue signals come in through the MIC pin. At each sampling period, the input is compared with the 10-bit D-to-A output level which, in turn, is produced by an estimate integrator and syllabic integrator, based on data from the previous sampling period.

Comparator output data are directed to external d-rams. Because there is a refresh counter on-chip, no external parts are required to send the data stream to external TMS4164, TMS4256 or TMS4C1024 d-rams. (The type of memory is selected using the mode-selection pins).

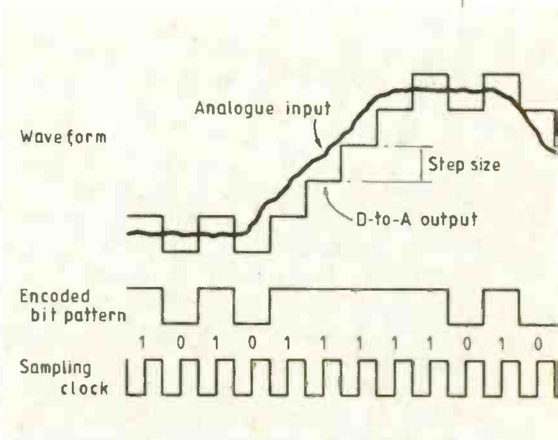
Each recorded bit is addressed by the TMS3477 address counter and when the recording ends – either because the STOP command has been sent or because end-of-memory has been detected – the corresponding stop address is latched into the stop-address register.

To play the recording back, PB is set and the TMS3477 starts reading from the lowest address. It stops when it reaches either the stop address or d-ram end-of-memory address.

The encoded bit stream from memory is passed through the 10-bit D-to-A and out through the SPKR pin 3. High quality is achieved by adapting the step voltage waveform using a 64kHz (typical) over-sampling clock, and PAUSE works during both recording and playback. Operation restarts when the relevant command is issued. Operation recommences at the memory address stored at pause. The STOP command, on the other hand, resets all other functions to begin a new recording or to playback from the start.

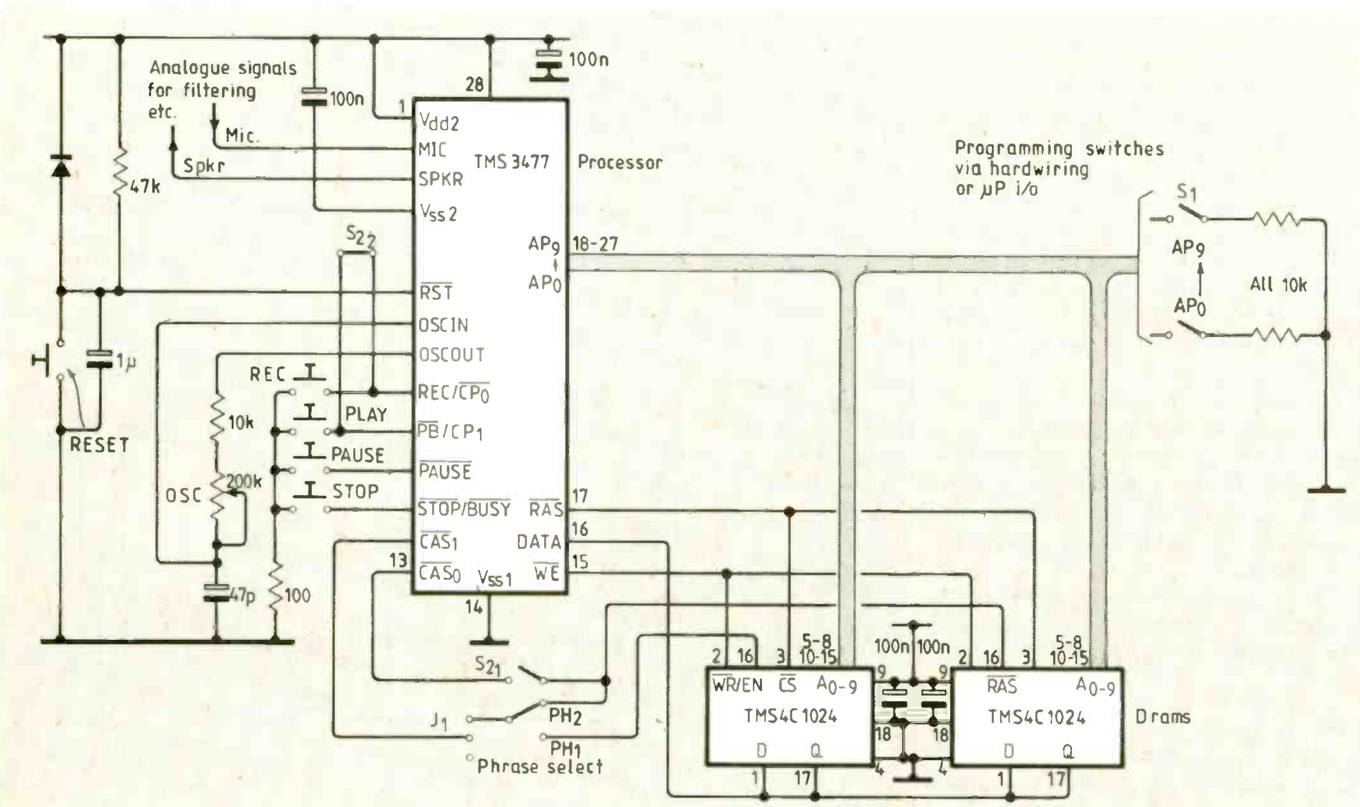
There are some useful variations on this basic operating procedure. First, it is possible to store two different recordings in external memory with fixed or variable lengths to allow, for example, an answering machine to be provided with a short recorded message and longer recording of incoming calls.

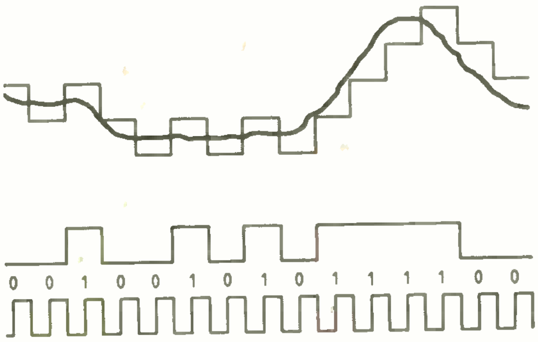
A cyclical recording mode can be set



The TMS3477 uses a CVSD (continuously variable slope detection) conversion technique for digitising speech.

The speech processor chip includes a refresh counter for direct interface to standard d-ram products. 2MBytes provides around 30s of message recording at 64kHz sample rate.





The analogue signals into and out of the processor chip require filtering with conventional low pass circuits to remove alias responses.

to make sure the latest speech data are always recorded in external d-ram. There is also a speech monitor facility which plays back the encoded data in real time whilst recording.

Designers can change the speed of the data sampling clock to provide the best trade-off between storage capacity and recording quality. The built-in oscillator can be varied between 250kHz and 492kHz (164kHz is the lower limit for the TMS3477A) and should be fine-tuned using a variable resistance. Data sampling frequency is determined by the oscillator frequency and the base data sampling clock

$$F_{DS} = (F_{OSC} \times F_{BDS})/320$$

F_{BDS} is pin-selectable as 16, 32 or 64kHz, hence the most faithful recording is achievable at 492 × 64/320, or 98.4kHz. Yet at 64kHz, two 1Mbit d-rams will only hold a 32s message.

A data-compression mode has also been included when the contents of the 10-bit D-to-A register are left-shifted by two bits, providing an eight-bit compressed value. It is not recommended to use this mode during recording – the facility is intended for emphasizing small signals during playback.

Implementation

Suitable external voice memories are TMS4164, TMS4256 or TMS4C1024; a maximum of two devices can be included. For phrase selection, a toggle switch is used. PH2 (up) connects CAS 1 signal to IC_2 and IC_4, whilst in the down position (PH1), CAS 1 signal is connected to IC_1 and IC_3. When the one-phrase/one d-rom configuration is selected by the mode-select key, DSW2 (1) switch is turned off, allowing selection of phrase 1 or phrase 2 by means of the toggle switch. With one-phrase/two d-rams selected, the toggle switch must be set to PH1 (down) to turn the DSW2 (1) switch.

Keyboard

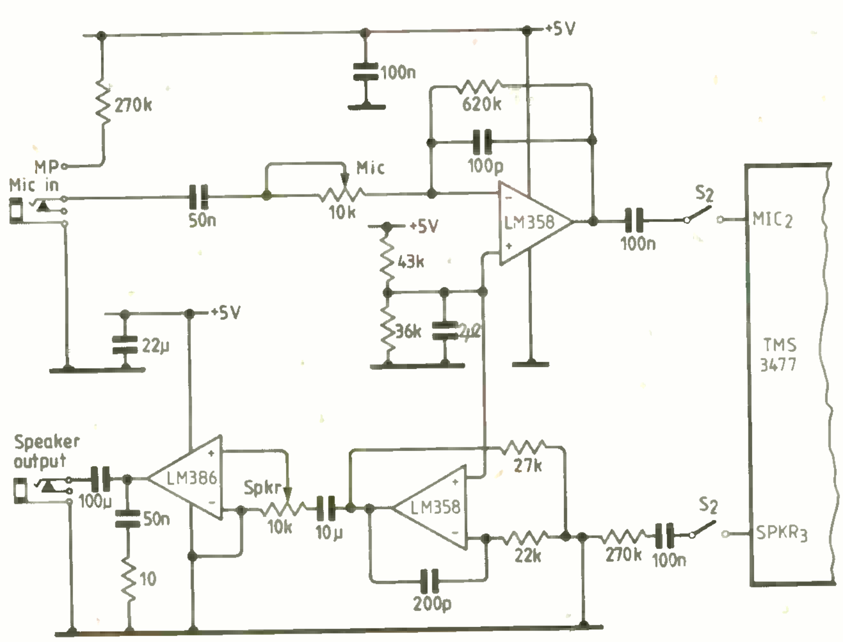
The TMS3477 is designed for simple keyboard interfacing through direct connections to pins 8, 9, 10 and 11. Each command is transferred by switching the relevant pin to a low stable level for at least 32 ms.

More complex interfacing to a microprocessor is possible through these pins when the CPU interface mode is selected by programming pin AP5 at power-on. Pins 8 and 9 are then assigned as command ports, with command patterns transferred to the TMS3477 by means of a high-level strobe on pin 10.

TERMINAL INPUT			COMMAND
PIN 8 (CP0)	PIN 9 (CP1)	PIN 10 (STB)	
LOW	LOW	High level strobe	PAUSE
HIGH	LOW		PLAYBACK
LOW	HIGH		RECORD
HIGH	HIGH		STOP

The BUSY signal available from pin 11 is active when a low level is present and signifies that the TMS3477 is recording, playing back or in a paused state. The microprocessor should be in a wait state at this time, resuming operation only when the STOP command is issued.

The CPU interface mode allows complex 'tape recorder' applications to be built up, including multiprocessor architectures. ■



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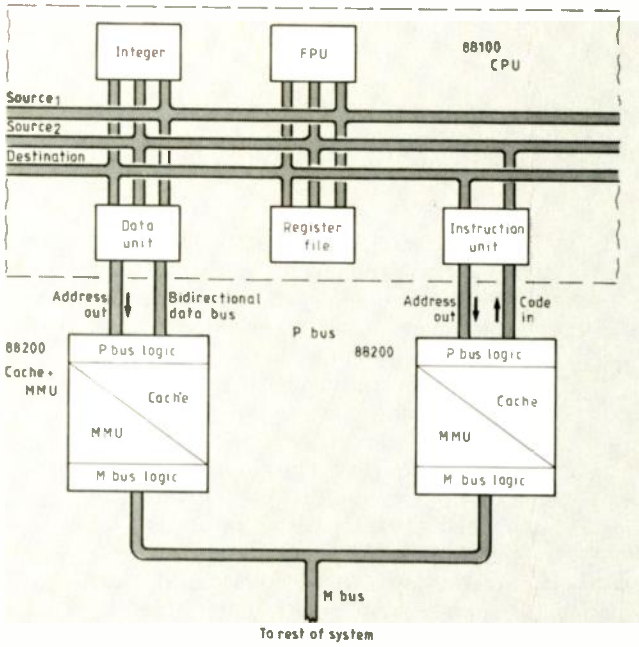

In Motorola's M88000 risc family, the 88100 CPU talks to the rest of the world through the P-Bus Harvard architecture.

that the company has released its own entry into the risc wars, in the shape of the M88000 series. The M88100 CPU and 88200 cache and memory controller make up a very powerful chip set, which should do well in the battle for the market place.

Most risc processor designers have taken steps to improve the amount of data that they can get in or out of the chip at a time, since this is a major bottleneck for processing speed. In the 88100 they have gone to great lengths by using a full Harvard architecture, where data memory and program memory have their own address and data buses making four separate buses in all. Each has its own pipe-line and a large, fact cache memory which operates concurrently with the other three. This design allows the chip to have a lot of information being shifted to and from main memory at a time.

Inside the processor the design again encourages concurrency; there is an on-chip floating processor (which operates simultaneously with the main integer processor) and there are three separate data buses inside the chip (for data flowing from two source registers and into one target register). There are 32 registers (as in the R3000 R0 is hard-wired to 00) which employ sophisticated scoreboarding techniques, to allow several operations to go on at once; under ideal circumstances the CPU could be holding as many as 11 different instructions, all at various stages of execution and accessing different registers.

This all adds up, so that a M88100 running at 20MHz delivers a reasonable 17Mips or 7Mflops. Whilst it isn't the single fastest or most powerful risc device, it does respectably well against some stiff competition and offers some very elegant features.

With the technological and marketing might of Motorola behind it this chip isn't going to fail but just how well it will do is an open question.

● See also Two approaches to risc: MC88100, *EWW*, July 1988 pp637-642.

AMD 29000

The Am29000 is a conventional risc design that turns in a respectable 17Mips. Like the others, it is a 32-bit machine with a load/store architecture, with on-chip pipeline and cache. It has a modified version of the Harvard architecture, which uses three buses to communicate with the outside world (bidirectional data, incoming instructions and a shared outgoing address bus). The address bus is pipelined and so data and program can be accessed simultaneously. This arrangement supposedly alleviates the von Neumann bottleneck without the complexity of a large pin count or the expense of a full four-bus Harvard architecture. It is an integer-only device – its associated floating-point coprocessor is the Am29027.

Internally, the 29000 is slightly unusual in having a very large number of useful registers. The designer has a tricky decision to make in how many to include: if there are lots, then the processor will be more flexible and will need fewer memory accesses. On the other hand there will be a bigger decoding overhead (which introduces delays), increased fan-out on all the internal gates and more circuitry to implement the registers. Some research seems to show that about 28 registers is the optimum and most designers seem to agree (Intel, MIPS and Motorola all have 32 registers and Acorn has 27). AMD has decided power and flexibility outweigh the other factors – it has included a whopping 192 registers. Any of these can be used for arithmetic or logical operations, or as a data pointer. They are organised into 12 pages of 16, to support task-swapping and procedural calls. In contrast to the sparc these pages are totally separate (non-overlapping). For fast applications (multi-tasking, real time control etc.) it is possible to switch to a new page, with fresh registers and new pointers, in only 17 cycles – about 600ns.

The 29000 can address gigabytes of virtual memory per process, with up to 256 processes available (this is another feature to help multi-tasking applications). This is helped by having a look-aside buffer to translate virtual to physical addresses. There is an on-chip cache, but with only 64 words it is unusually small.

This is currently the only risc chip that has a full development support system. There's a source level debugger (for AMD's C compiler), a target resident monitor, in-circuit emulators and an architectural simulator.

For any serious user this is a vital set of tools and it is perhaps the biggest plus that this chip has to offer.

Performance is an acceptable 12 VAX Mips (reputable manufacturers normalize their chip's speed ratings by giving them in terms of equivalent VAX 11/780 instructions). AMD promises to have a 50Mips version next year and expect the price to fall to under $1/Mips. The number of registers (with fast page-swapping), the ability to have several processes running and the support makes this chip better suited to high-end embedded control applications than the number crunching tasks that are usually considered risc's domain. AMD cites applications such as laser printer controls, ISDN switching nodes and robot controllers. ■

● See also Second-generation Risc processor, the AMD approach, *EWW* July 1988, pp 689-691.

The cross-field antenna in practice

Can the CFA really work? Bypassing the complex theory of the controversial March article*, C. Bryan Wells has produced practical versions which suggest that it does.

Mainly because James Clerk Maxwell is my scientist hero of days gone by I carefully read the March article and became almost hooked when I came across the words quoted here from the final paragraph. For some time I had been thinking along the lines that an antenna is really a coupling device – coupling electromagnetic energy to space – and that there ought to be ways of achieving this process as alternatives to monopoles, dipoles and loops. Was this one of those appealing concepts with seemingly great initial promise whose claimed potential is never realized in practice? Indeed, could it possibly be a hoax?

There seemed to be only one thing to do – to see if the cross-field antenna (CFA) could be made to work. The first step was to extract as much information as possible from the diagrams and photograph on page 218 by scaling to the one dimension quoted – 70cm overall height (see **Fig.1**). The following dimensions are estimates: E cylinder height; D plate overall diameters, and the diameter of the feeder access holes in the D plates (because of the obscuring effect of the eight supporting and insulating rings in the middle of the "barrel").

I started by making a half-size version, winding aluminium foil around powdered milk drums and cutting off the tin plate ends to form the D plates and then forming seven annular support members from polystyrene packing material. The 50% power split and phasing were arranged as in **Fig.2.** Perched on an easterly-facing window ledge, this unit yielded a number of successful contacts with British, Irish and European stations on 7MHz, at 100W.

Since then I have engineered a second half-size version, this time using coffee tins, and a further version properly fabricated from aluminium to the dimensions in Fig.1. This full size CFA

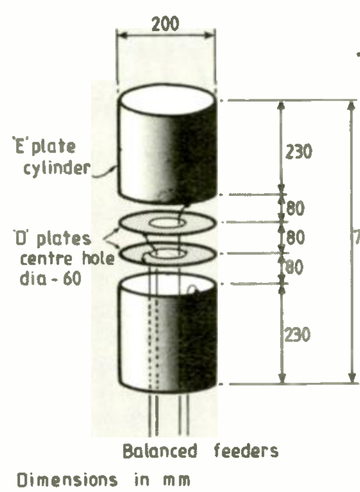

Fig.1. Barrel shaped cross-field antenna. Dimensions are estimated by the author from the photograph and Fig.1 of the article by Kabbary, Hately and Stewart (March issue).

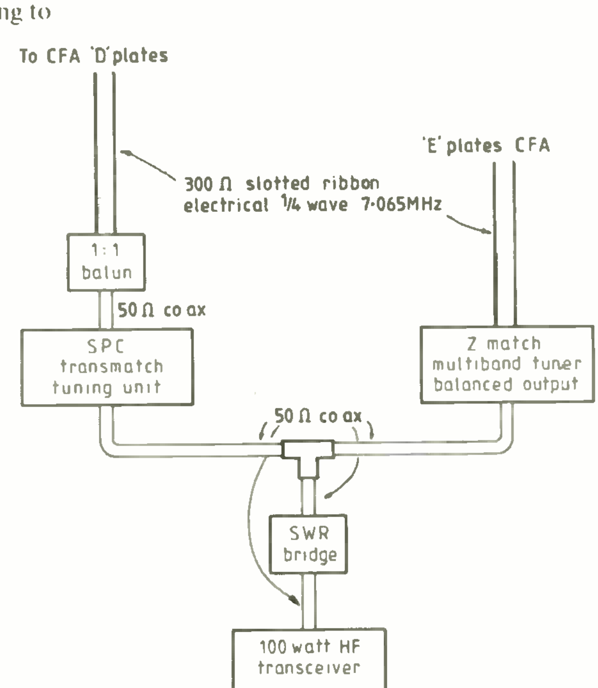

Fig.2. Feed arrangements, showing a quadrature feed for the E and D plates. In practice, a balanced L-network was used to give a 90° shift while eliminating the need for a second quarter-wave phasing section.

*F. M. Kabbary, M. C. Hately and B. G. Stewart, *Maxwell's equations and the cross-field antenna.* Electronics & Wireless World *March 1989, pages 216-218. For a rebuttal, see also Letters, July, page 682.*

shows considerable promise. At night the results are almost as good as both my double zepp and an 82m circumference vertical loop, both at about 10m. The full-size CFA is mounted against the peak of the roof space in the house at about 8m above ground.

Precautions

I have taken precautions such as earthing other antennas, in case coupling to them was responsible for the results achieved, and checking that the feeders were not doing most of the radiating – with an efficient antenna matching unit it is possible to make any piece of conducting material into some kind of RF radiator.

These checks were threefold. First I removed the quarter-wave lines and directly fed the device through 45cm lengths of 300Ω ribbon with a balanced L-network phasing circuit interposed between the feeder and matching unit on one side and the CFA then mounted about 30cm above the matching unit. This arrangement worked satisfactorily if slightly down. Next I reintroduced the quarter feeders and moved the CFA to the peak of the roof space. I reasoned that if the feeders were doing most of the work, elevating the CFA so that the feeders had a 6m vertical run should bring about a very significant improvement. This did not occur. The reception improvement was just noticeable by ear.

The third check was to compare 300Ω feeder radiation with a double zepp as load, at 80W, with that of both the CFA feeders taken separately, each taking approximately 50W. The detector was a 6V flashlamp bulb to which was connected 25cm of 300Ω ribbon, shorted at the open end. This check showed that radiation from the CFA feeders was much less than that from the double zepp feeders or from a well matched twin-lead dipole. To detect the CFA feeder radiation it was necessary to clip the 25cm of detector ribbon to the CFA feeder. There was no bulb glow with a 12mm separation.

To check radiation from the CFA itself I used a 240V neon bulb, again with 25cm of shorted 300Ω ribbon attached. This insensitive probe was incapable of detecting feeder radiation, but showed a distinct glow when positioned within 8-10cm of the CFA excited with 100W (2×50W).

It is still possible that all the CFA does is to provide a useful metallic radiator "tuned" by the antenna matching unit. However, in a great deal of experience with extended coils, loaded whips, helicals etc., I have not been able to produce results which compare with those I have obtained with the CFA. It is also possible that I have not achieved the optimum in phasing, power split and matching.

*The important features of these antennas are (i) that they are extremely small, excellent receivers, powerful, efficient radiators and (ii) that their physical size is independent of the radiated wavelength – an unprecedented concept in antenna theory and design.**

I cannot claim that the CFA is as efficient as a full-size wire dipole, although it is only very slightly down on a 40m twin lead dipole, also up in the roof space, which I have used as a reference.

How does it work?

If I have come to believe that the CFA concept has some real merit, I ought to be able to put together a practical explanation of how it works, without recourse to rigorous mathematical analysis. I start with two simple propositions:

- An antenna is a means of coupling electromagnetic energy to space and usually comprises widely distributed inductance and capacitance. Most, but not all, antenna ideas involve resonant half-wave elements in some way.
- Half-wave resonance can be produced in very small antenna designs (small compared to a wavelength) usually by using lumped constant inductors and or capacitors.

If the CFA concept is in fact a new and reasonably effective way of achieving "space coupling" then it might be considered as a "lumped constant" version of a device analogous to our normally understood antennas.

The power carried by an electromagnetic wave is proportional to the product of the electric field E and the magnetic field M. If some way can be found of augmenting either E or H then this will result in a greater overall field intensity.

In the original CFA article it is emphasized, and the authors claim to have demonstrated, that "the H field may at any time be the combination of two separately induced fields from independent types of sources, i.e. charge motion and capacitor displacement current".

If the "displacement current field" in a normal system has been under-used or not really used at all until now, then the CFA is a means of exploiting it and thereby augmenting E×H.

The device is relatively small and so its coupling to space in comparison to a normal, well distributed, antenna is less efficient; but the higher field intensity compensates to some degree. Just to what degree compensation can be achieved is, I suppose, the underlying purpose of the experiments.

The CFA in action

Perhaps the most important problem is the question of the required phase relationships between the 50% power split to D plates and E cylinders. After trying 180° (on 7.065 MHz.), with an extra electrical half wave to one of the elements, I found greater success in terms of transmit reports and reception with a 90°, quarter-wavelength addition. I eventually replaced this additional quarter-wave line with a balanced L network at one side of the origin of the two power-splitting quarter-wave lines, with no apparent change in performance. Using a twin variable capacitor in this network gave the possibility of fine adjustment. As previously stated, this arrangement follows the preferred amateur radio method of splitting power between two phased verticals and achieving quadrature phasing. (The network values were calculated after making approximate measurements of plate and cylinder impedance using a noise bridge).

It seems that, whatever phasing method is used, it becomes difficult to maintain the 50 – 50 power split between plates and cylinders. RF voltage measurements are extremely difficult to make with balanced lines for this purpose. However, splitting the power in co-ax. and then feeding the quarter-wave lines through baluns with RF

voltmeters placed immediately before the baluns can also be misleading. Any slight difference in the standing wave on the quarter-wave feeders in the unmatched, or poorly matched system, shows up as RF voltage differences, which may, or may not mean an asymmetric power distribution; the only answer so far to these problems is as shown in the attached diagram. Split the power in co-ax. between two matching units, feed the quarter-wave lines through baluns, tune both matching units for best reception and finally trim for a flat line to the transceiver. Do not worry too much about the accuracy of the power split or the exact phasing relationship.

Using two matching units has also facilitated excursions onto the 80m and 20m amateur bands. This has raised another puzzle: whereas on 40m the results from the CFA come close to the normal wire antennas at distance of 500 miles plus, particularly in darkness hours with the possibility of lower angle propagation, the experience on 20m does not show anything like such dramatic improvement. However, on 80 the CFA results are always close to the wire antennas and during darkness pretty nearly equal. The only explanation that I can produce for this experience is the question of compromise. The CFA is obviously a compact antenna, with the associated limitations. Most, if not all, amateur radio antennas on both 40 and 80 are compromises so far as height is concerned. In the trade-off between the compact CFA and the "low-height relatively low-frequency" wire antennas the CFA does not fare too badly. At 20m, where many amateurs can erect beams and dipoles at a height of half a wavelength, the CFA suffers in comparison. I have to add the note here that band conditions on 20m, 15m and 10m have been relatively poor with a lot of short-term variation during the experimental period and that has made comparison difficult. I must mention that the experiments on 20m and 80m have been made with the feed arrangements as shown for 40m and all band change adjustments being made with the matching units.

It has occurred to us that the employment of delay lines especially designed for that purpose might be another approach to phasing experiments, if they can be obtained at reasonable cost, although having to provide separate lines of this kind for all nine amateur HF bands does seem a little bit uneconomic.

So far as the CFA's element spacing and phasing arrangements are concerned it is difficult to find any critical adjustment points that affect receiving performance. This leads me to suspect that the feed and phasing arrangements I have used are not ideal.

The CFA shares a roof space with a UHF television antenna, also vertically polarized, and an outdoor television antenna is only about 1m above it. So far no television interference has been apparent. This seems to confirm one of the qualities claimed for the CFA, that it does not easily couple to conventional antennas in its vicinity.

Earthing the main antennas gives an improvement, small but detectable by ear, in reception using the CFA. ■

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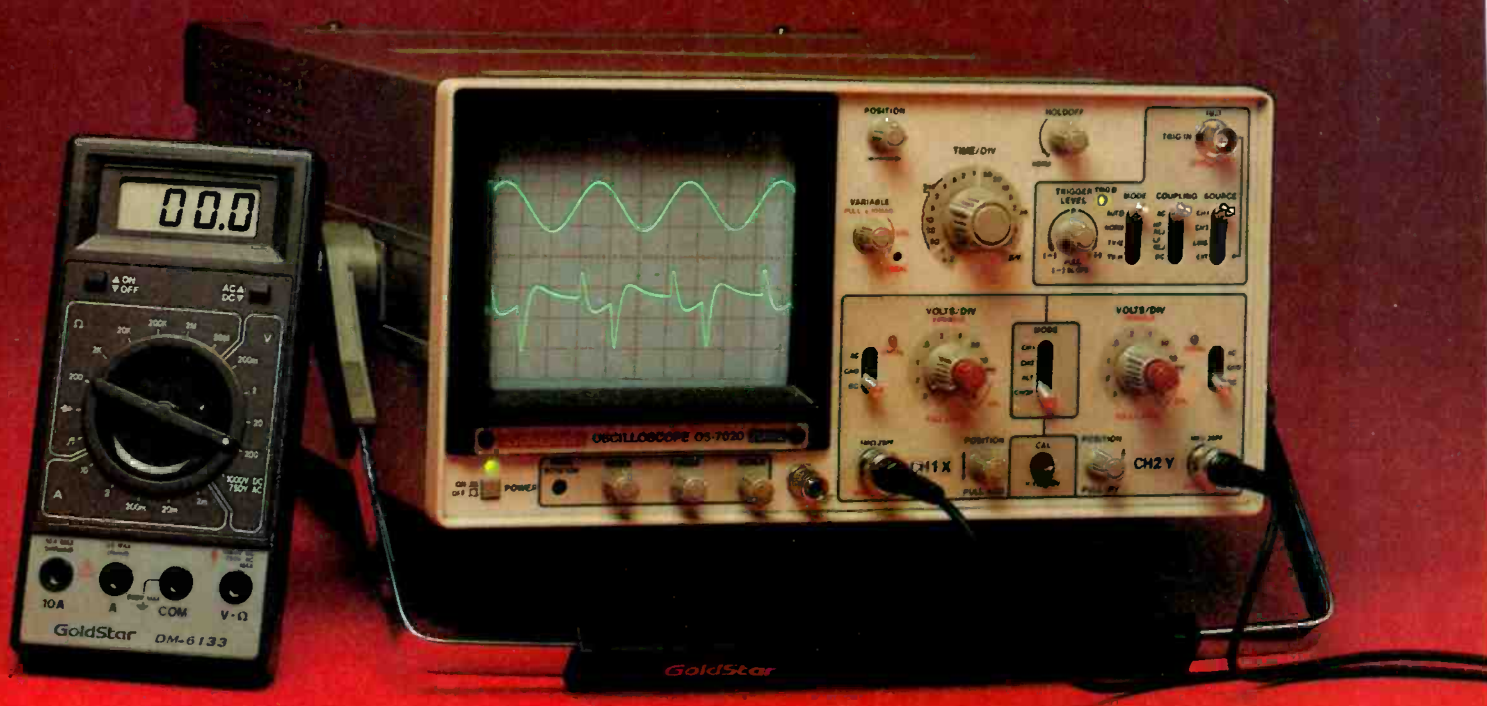

Analogue emulation with Spice.age

Stephen Franks reviews Spice.age, an easy-to-use PC-compatible circuit analysis package for design and education

Spice.age is an analogue circuit simulator and consists of four modules: for frequency response, DC quiescent analysis, transient analysis and Fourier analysis. While the user need only buy those modules that are of interest, they form a seamless program when used together.

The software is intended for teaching in university or technical college; it is ideal for use as part of a course in electronics. It can also be used by circuit designers to check designs before reaching for the soldering iron, although it is a little slow for the more complex circuits.

The software runs under Digital Research's GEM – a graphical "front-end" designed to do all the hard work involved in driving the screen and printer, and accepting commands from the user. This has the advantage that anyone familiar with GEM will be immediately comfortable with the package, and provides the confidence that, as new printers and plotters become available, drivers will be written to allow them to be used.

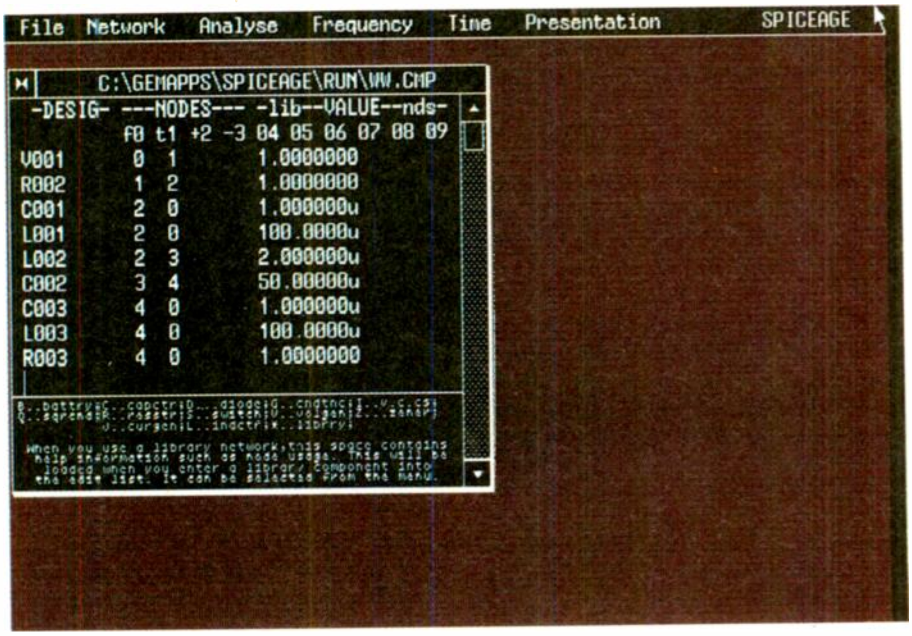

Fig. 1. A simple passive band-pass filter circuit, as entered into Spice.age.

Operating environment

Spice.age will run on any IBM PC, AT or PS/2 or compatible under DOS 2.0 or later, and with at least 512K of ram. It uses GEM (version 3) which is supplied with the software and requires a graphics screen; GEM supports most graphics standards, including Hercules, CGA, EGA and VGA. Output is also via GEM and, although the range of drivers supplied with the package is limited, device drivers are available for almost any graphics printer or plotter. A numeric coprocessor is not required, but can be used if present. A mouse is useful, but the software can be used without one. The computer must have either two floppy drives, or one floppy drive and a hard disk.

Installation

Installation is a three-stage process: registration, GEM installation and Spice.age installation. This entire process is clearly described in the manual, and takes very little time.

Registration involves embedding the name of the user into the software; until this is done, the software cannot be used. The name typed in must agree with that given to the manufacturer, who provides three numeric keys which must also be typed in. If the numeric keys match the name, the software is unlocked, and installation can proceed. This is one of the better copy protection schemes available, since it allows the software to be copied to make back-ups but allows immediate identification of pirate copies.

Once registration is complete, GEM must be installed – that is, assuming that the user does not already have a copy. The documentation for this part of the process is much less comprehensive; the full GEM documentation is not included, and although on-screen help is provided, it is not always clear what to do next. For anyone reasonably familiar with installing software, however, this section will not present any problems.

Finally, Spice.age itself is installed, using the self-install program provided, which does all the work of creating sub-directories and copying the files into the right places.

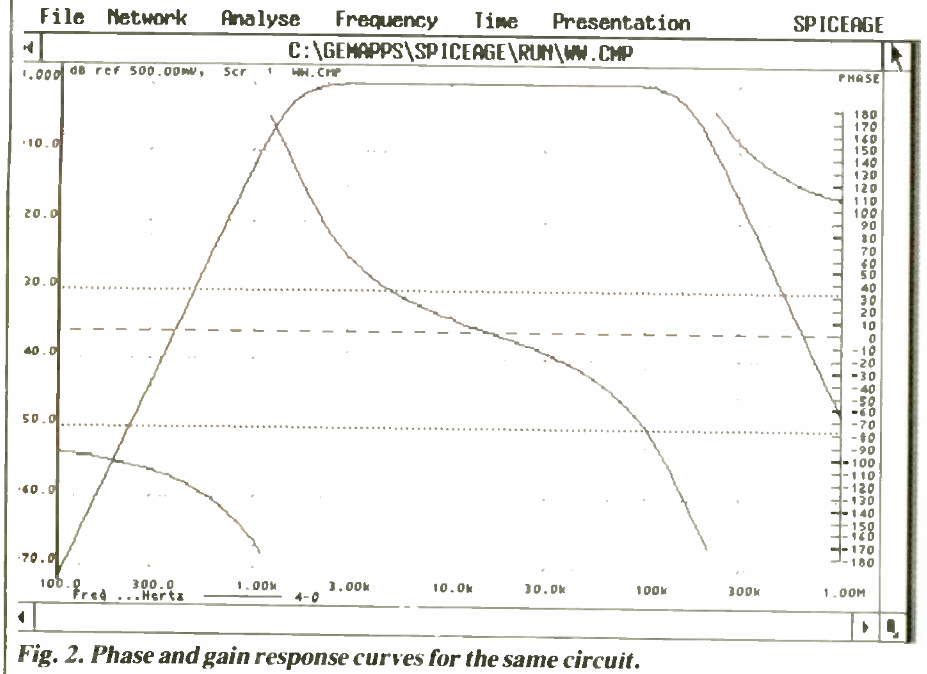

Fig. 2. Phase and gain response curves for the same circuit.

six different ways. The result is a clean-looking graph, which is delightfully easy to produce.

As described earlier, the quiescent conditions of the circuit are analysed. A table shows the voltage at every node in the circuit.

Transient analysis produces an oscilloscope-like graph showing the response of the circuit to a variety of stimuli: impulse, sine, step, triangle, ramp, square and pulse train. It is possible to pre-charge reactive components to quiescent conditions, and to have more than one voltage (or current) generator. The stimulus always starts at time 0, but the graph can start at any time before or after this. Up to four nodes in the circuit can be shown on the same graph.

Fourier analysis is performed on the data generated by the last transient analysis, which is a little confusing at first. However, once grasped it is easy to set up and use and, like the other modules, produces clear, uncluttered text-book graphs.

Entering the circuit

The circuit is entered by assigning numbers to each node in the circuit, and typing in a list of components with the nodes to which they connect. A very helpful feature is the ability to assign "help" text to items in the library of components. When a library item is specified, the help text appears at the bottom, giving the nodes that need to be connected, along with other useful information.

Although there are limits to both the number of nodes and the number of components, these are high enough not to restrict normal use.

Circuits can be stored on disk, and entire circuits can be stored as a single library item, to be built in to more complex circuits later. The basic components available include the normal resistors and capacitors and a diode (modelled on the exponential diode equation well-known to all students). There are also components such as a square-law conductor and a voltage-controlled current source, intended for use in modelling more complex devices. The library items provided with the software include a general-purpose transistor (in both p-n-p and n-p-n form), a 741 op-amp, a 1:2 transformer and a field-effect transistor. Also provided are a couple of c-mos logic elements.

Circuit analysis

The frequency analysis module produces the usual gain and phase-response curves. To produce accurate curves, the circuit is first analysed for quiescent (DC) conditions before calculating the small-signal results. Strangely, the DC conditions cannot be viewed unless the second module is purchased; surely these two modules could be combined? The small-signal analysis assumes that all signals are reasonably small, and quite happily indicates 100V output signal from a 10V power supply. It is of course normal practice to assume that signals are reasonably small, but it is especially easy to forget this when all the calculations are done for you. The graphs produced are self-scaling, and each axis can be log or linear, with the dB reference, if used, defined in any of

Using the software

Spice.age was written by a senior lecturer at a technical college – and it shows! It is easy to see many different ways that Spice.age could be used to teach: apart from allowing students to test their designs, it could be used to demonstrate modelling of semiconductors (the library contains the Moll-Ebers model), and it is possible to set up excellent examples of the effects of selecting the wrong samples for Fourier transforms. For more advanced students, it could also be used to teach computer modell-

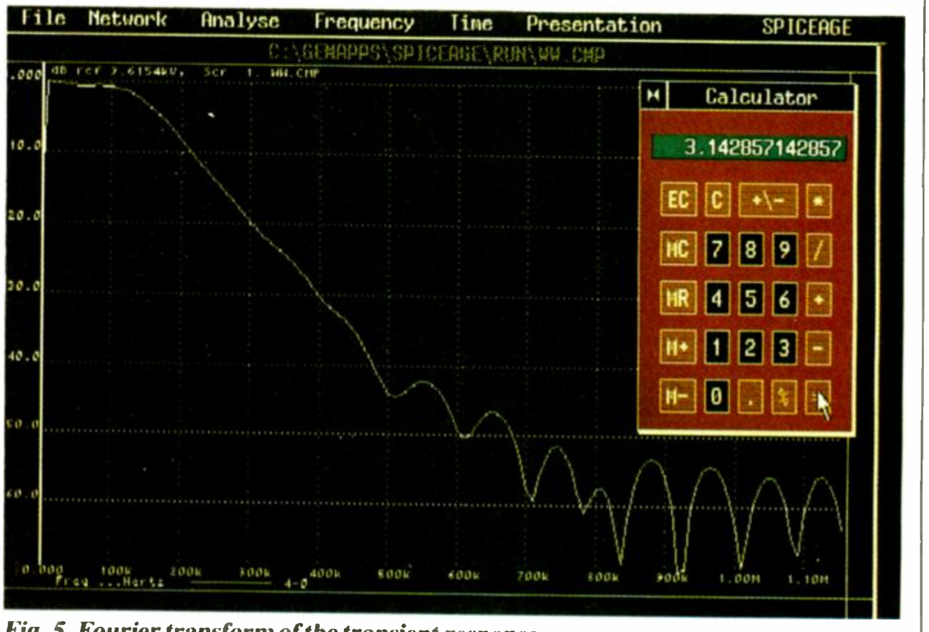

Fig. 5. Fourier transform of the transient response.

ing: for example, it can be made to show the effect of selecting unsuitable sampling rates.

Although the software does function very well, there are a few aspects that could be improved. There is no provision for examining the effects of component tolerances: such a provision would make the software able to cope with even more teaching situations. The only other problem with the package is the speed of calculation. On a fast machine (a 20MHz 80386 with coprocessor), it is possible to change some aspect of the circuit and re-analyse to see the result. On slower machines the time taken to analyse a moderately complex circuit (such as an active filter) is a disincentive to experiment. While there is a minimum amount of arithmetic implicit in the nature of the software, it may be possible to improve the speed by careful optimization and if so this would be time well spent.

The software is very robust: it is not possible to select an option that does not make sense and the software coped perfectly with everything thrown at it. Standard of finish was considerably better than a lot of educational software: unlike those provided in much software (including much more expensive packages), the error messages were sensible, and gave sufficient information to put right whatever was wrong.

There has been great attention to detail in the design of the software, mainly spent on making it as easy to use as possible. For example, when entering the value of components, almost any form is accepted: 1K2, 1200, 1.2K, 1.2E3 are all accepted as the same value. This care has been extended to all parts of the software, making it very flexible while still reasonably easy to use.

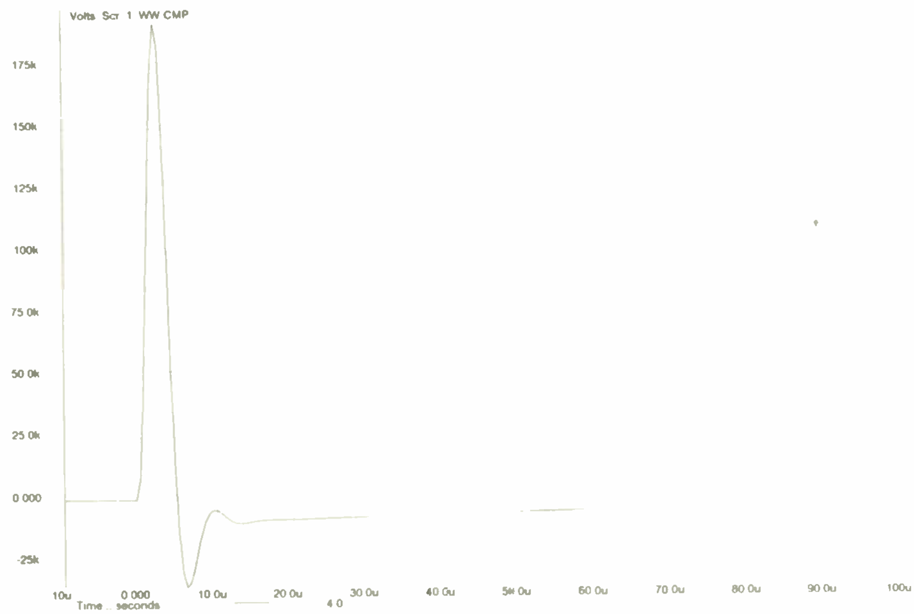

Fig. 4. The transient response of the circuit to a 1V impulse. Note the peak in excess of 175kV – try seeing that on an oscilloscope!

Printing and plotting

The output side of the software is a little peculiar. Normal practice with GEM-based software is to have a "Print" option in the "File" pull-down menu, this often asks for further information before starting to print. Once the information is gathered, an application will normally automatically run GEM's output program, which handles the output and returns to the original application.

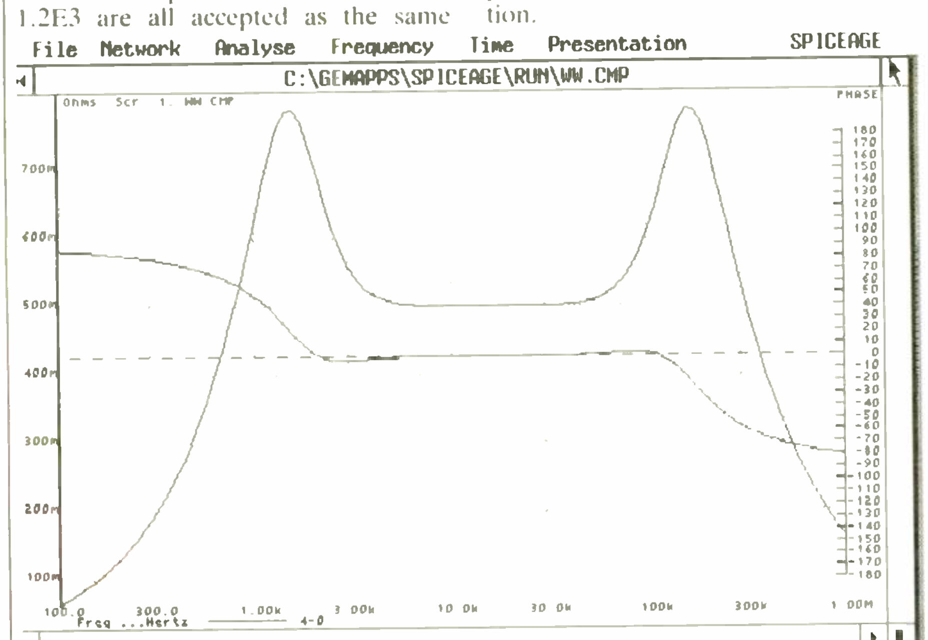

Fig. 3. Impedance versus frequency for the same filter.

Spice.age on the other hand, requires the user to do all this manually. The "Presentation" pull-down menu contains a "metafile" option, which may be either selected or deselected. While it is selected, a copy of every graph generated will be sent to disk as a file, the user being prompted for a name every time. Once all output is generated, the user must quit Spice.age, start the output program, and give it the name(s) of the files to print. To continue with Spice.age, Output must be terminated, and Spice.age started up again.

This is rather tedious and not at all intuitive, which is what the GEM environment is all about. It requires the user to handle the temporary files used, to delete them after use, and to ensure that they are not overwritten until printed out. This is especially unsuited to a teaching situation, where it is likely that several students will use the machine in succession.

GEM ensures that all output devices are used to their best resolution, completely independently of the screen. Drivers are supplied with the software for all popular dot-matrix printers (but no plotters) and further drivers for both printers and plotters are available for £15 each. Currently all output is monochrome, although colour may be supported in future releases.

Final output is identical to the screen, but at the best resolution of the printer. There is no facility to add titles or other annotations, but all relevant information is automatically included.

Support

A help-line number is operational from 2.00pm to 4.00pm. Since the software has not generated any genuine problems, questions had to be devised to assess the service. The responses were uniformly good: simple questions were answered immediately, and one more complex query was referred to the author of the software. In this case, a return call was promptly made with the answer.

It is common to underestimate the importance of a service such as this, but a good help-line can save a great deal of time. This service appears perfectly adequate, even to the extent of trying to anticipate problems, and giving helpful information regarding a minor bug in the GEM environment; it would appear that when installing GEM on a dual-floppy computer, a "disk full" message can be generated. The cure is simple enough, but given that educational establishments are likely to have such machines, it would be even more helpful to include a note with the software, describing the bug together with the cure!

Manual

The manual manages to be simultaneously very good and very bad. For those meeting the software for the first time, the manual provides a clear introduction, including taking the user through a few examples provided on disk. Once the basics are learned, however, the manual is much less useful: despite an apparently comprehensive index, it proved very difficult to find information as the need arose. It is in single-sided A4 format, which makes providing copies for the students easy – and the licensing arrangements allow for limited copying. This is a very sensible move, as it keeps the cost of the software low (at least for multi-user sites).

This piece of software does just what it sets out to do: that is, to provide an aid to teaching electronics. It relies heavily on the lecturer to build it into any given course, but can be used at many different levels. The ease of use of the software is such that it should not distract from what is being learned. It contains many idiosyncrasies, but these are balanced by many minor but useful features that make it, overall, a very worth-while teaching aid.

Price is £70 per module, or £245 for all four modules. For educational establishments, an eight-user licence is available for £499, and provides eight user disks, one master manual and permission to make eight copies of the manual. Further copies are then £35 each, which includes the user disk and permission to make a further copy of the manual. Ready-made manuals are available for £15; but a site may not have more manuals than the number of licensed users. ■

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Heating the sky mirrors

The letter from Tony Hopwood ("Radio Mirror" *E&WW*, September 1989, page 877) shows how ionospheric hot spots can be produced by high-power terrestrial transmitters. His observations appear to be novel in recording the presence of hot spots due to microwave satellite up-link transmitters. However, ionospheric heating and its potential use for extended-range VHF scatter communications and long-range "monitoring" has been recognized and investigated for well over a decade. Under the heading "Artificial radio aurora" in *WW*, February 1975, page 86, I wrote:

"In his 1966 inaugural address as president of the IEE, J.A. Ratcliffe noted that when the long-wave broadcasting station at Droitwich is switched on the temperature of the electrons at a height of about 100km increased by about 45°C. This technique of using radio transmitters to heat up the electrons in the ionosphere is being investigated in the United States and the USSR as a means of producing artificial radio aurora to permit scatter communication on frequencies up to UHF over distances of some hundreds of miles. Details of this work, on behalf of the US Department of Defense, have recently been given in two American amateur journals with a view to further participation by amateurs. Much of the basic research has been done by the Institute for Telecommunications Sciences (ITS) and the Stanford Research Institute and has already shown that this propagation mode could be of interest to amateurs. For example, on May 11, 1972, K7PXI in Phoenix was heard via ARA in Socorro, New Mexico. In these tests, very high-power HF transmissions (typically about 5MHz) are beamed upwards with an ERP of the order of 5 megawatts, raising the temperature of the electron gas, forcing it to expand along the magnetic field and so permitting scattering from the field-aligned irregularities.

"The tests have shown that the effect on forward-scatter signals is almost coincident with the switching on and off of the 'heater' transmitter both in the F-layer and the E-layer. High-power transmitters suitable for this work currently exist at Platteville, Colorado and at Arecibo, Puerto Rico and also in the USSR at Gorki."

Since then it has also been shown that it is possible to generate ELF waves in an artificially-heated ionosphere by the non-linear "mixing" process that was recognized in the 1930s as the Luxembourg Effect.

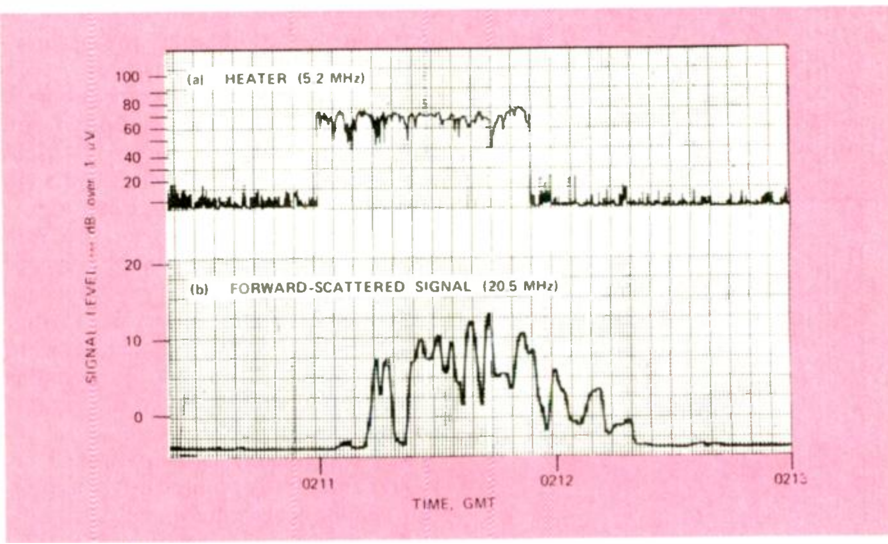
A paper by Min-Chang Lee and J.A. Fejer of the University of California, ("Theory of short-scale field-aligned density striations due to ionospheric heating," *Radio Science* vol. 13, no. 5, 1978), noting that powerful radio transmissions from the ground produce a variety of modification effects in the ionosphere in addition to simple heating by ohmic dissipation reported: "One of the unexpected effects of ionospheric heating experiments was the generation of short-scale field-aligned striations."

Since we may safely assume the interest of military and sigint organizations in the practical applications of artificial radio aurora (ARA) it is not surprising that little has been published on the final outcome of the American experiments.

Much nearer to Earth, the possibility that large aircraft can, in specific atmospheric conditions, produce temperature inversions in the troposphere capable of sustaining VHF/UHF communications over ranges of about 450km has been attracting the attention of Australian radio amateurs. In 1985, stations in Melbourne and Sydney investigating communication by weak forward scatter were surprised occasionally to hear relatively strong signals from Ian Cowan, VK1BG near Canberra, roughly midway between them. Observations showed that the signals, lasting from just a few minutes to tens of minutes, coincided with the flight of large aircraft between Melbourne and Sydney.

Some of the Australians believe this can be entirely explained as a form of bistatic radar with signals scattered from the metal surfaces of the aircraft. But others are convinced that in some circumstances the large amount of heat discharged from the engines produces a temporary temperature inversion, with the geometric shape of its wake resembling a two-dimensional copy of an inversion produced in nature.

Brian Measures, G0HKR believes that this form of aircraft-enhanced propagation is due to aircraft exhaust trails (condensation trails or contrails): "In the tropical stratosphere, where the lowest temperatures are to be found, persistent contrails are formed by the aircraft exhaust gases. These gases contain sublimation nuclei, so causing supersaturation with respect to ice with radio signals possibly bouncing off the resultant ice particles formed in the contrail." This would account for the varying length of the openings depending on the creation of contrails in low-level or high-level saturation conditions with contrails either a short plume or of a long persistent nature. It would be interesting to know if such conditions show up on Australian radars or if there is always a Doppler shift of the order to be expected if the scattering is entirely from the aircraft surfaces.



An example from the American experiments in the early 1970s showing F-region scatter reception of signals on 20.5MHz over an Arkansas/California path at a time when this was above the MUF. Signal enhancement appears about 20 seconds after the "heater" on 5.2MHz is turned on, with the signal again fading into noise some 20 seconds after the high-power transmitter is turned off. **(Scattering characteristics of artificial radio aurora, by Victor Frank, WB6KAP, Ham Radio, *November 1974*).**

The problems with HF packet

The teleprinter began to replace morse for line communications during the 1920s; and attempts were soon being made, for example at the US Navy Research Laboratories, to adapt the machine for use on radio circuits. Difficulties were quickly revealed and it was another 20 years before radio-teleprinters could be used by navies on an operational basis over HF circuits, and then only with difficulty. HF signals vary in strength by 20-40dB, sometimes by 80dB; multipath propagation can result in time differences of from 1 to 3 milliseconds; clear channels are frequently not available. Unprotected HF circuits using teleprinters have typical character error rates, even on good paths, of $1:10^2$ compared with the $1:10^6$ often demanded for digital data.

All radio teleprinters are based on the Murray five-unit baudot code. CCIR Recommendation 476 established the Dutch TOR (Teleprinter-over-Radio) protocol – a single-channel synchronous system using a seven-unit error-detecting code with a modulation rate of 100 baud and a throughput of 50 baud if no repeats are requested, reducing in practice to perhaps 20-30 baud in poor but usable path conditions.

CCIR476 provides the same 32 character set (capital letters only) as the No 2 Baudot code plus six special signals. A small number of character errors may be printed; but a notable feature of SITOR and other members of the TOR family, including the amateur radio AMTOR established in the late 1970s by Peter Martinez, G3PLX, is its very acceptable performance on weak signals in poor radio conditions, often approaching the best that can be achieved on hand-sent morse by experienced operators. It can be received in a bandwidth of about 300Hz.

However, the fixed-rate transmission, with a maximum efficiency of 50% and the possibility of some uncorrected errors, makes it less than ideal for modern digital systems linking computers for which the standard ASCII code with its 128 character set (plus error detection) is needed. The emergence of "packet" systems for telecommunication circuits soon led to experiments to determine their possible application to single-channel HF/VHF/UHF radio.

Information is sent in packets of varying length, typically up to about 60

Antenna computers vindicated

It has sometimes been suggested that antenna engineering can be divided into two different eras – before and after computers. Nevertheless much of the work now carried out with the aid of computers is based on earlier work when only human intelligence and painstaking mathematical analyses were the order of the day. And it is only recently that there has been less need to remind ourselves that with computers as well as humans "garbage in results in garbage out".

Much of the current attraction of computers in antenna engineering stems directly from the development a decade ago of the Numerical Electromagnetic Code (NEC) with software based on the sophisticated mathematical "method of moments" procedure originally formulated, although not as a computer program, by R.P. Hartington in 1968. It is already clear that NEC has opened a new era in antenna analysis and design that is quickly overtaking the costly, time-consuming and not always reliable use of model antenna ranges, permitting the paper design of practical antenna systems, determining and modifying the directivity, gain, input impedance and radiation patterns.

The original NEC software required the use of a mainframe computer and was thus of limited appeal to field engineers. However, about 1982 the US Naval Postgraduate School in California wrote a simpler Mininec program for use with readily available personal computers. This team, and others including D.M. Pozar, have since further developed and amended such software which covers "thin-wire" antennas where only axially-directed currents flow on the conductors.

Dr Brian Austin (University of Liverpool) has recently pointed out ("Validation of microcomputer antenna codes", IEE Conference Publication No 301, ICAP89) that validation of Mininec and similar software is vital if any degree of confidence is to be generated in this form of computer modelling procedure. This can be done either by experimental validation using full-scale or carefully-controlled scale-model measurements or by comparing computer-generated results with published literature not based on computer codes.

Dr Austin has adopted both methods, although he has concentrated on comparing computer and non-computer analyses of a series of basic antennas including inductively-loaded short monopoles, capacitive end-loaded wires, simple forms of the Yagi-Uda antenna with wire elements, linear travelling-wave antennas, the corner reflector and also the interaction of antennas with metal supporting masts. His general conclusion is that "Mininec can be used with confidence to model a variety of antenna configurations, given

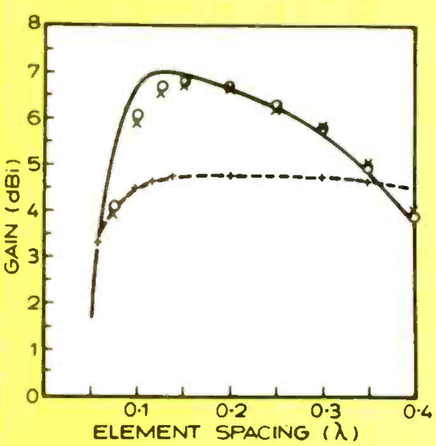


Fig. 1. Effect of reflector-to-radiator spacing according to Lawson (solid line), Mininec (rings), Viezbicke (plus signs, +) and Pozar (crosses, ×).

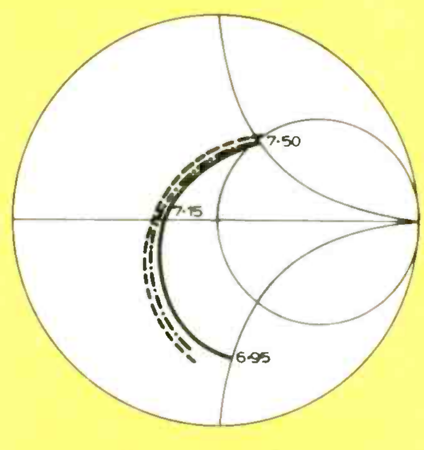


Fig. 2. Input impedance of the Yagi-Uda array, by Lawson (solid line), Mininec (dots and dashes) and Pozar (broken line).

characters at a time, with a selection of signalling rates up to 9600 baud or more. A number of stations can theoretically use a single channel in time-multiplex. The receiver will not accept for display any packet in which even a single error is detected. The penalty is that many more repeats are likely to be demanded than with TOR unless the path is of a quality most unusual for HF and by no means always available on VHF or UHF.

Although significant numbers of radio amateurs, and an increasing number of professional users, are now using the AX.25 packet protocol on HF, there is a growing body of opinion that radical changes will be needed if the system is to be widely used on HF. Douglas Lockhart, VE7APU, a pioneer of packet radio in 1978, has written: "When I developed it, it was intended for VHF/UHF/microwave. It is being used on HF but requires a 99.9% reliability of the bits getting through to be useful, because you have to have a whole set of bits coming through in order to receive them perfectly."

Paul Rinaldo, W4RI, editor of *QST*, believes the time has come for a re-think of the AX.25 protocol, taking into account multipath, intersymbol distortion, group delay, interference error bursts, excessive retries, etc.

Admittedly, ASCII codes overcome problems caused by the corruption of machine characters (carriage returns, line feed etc.) experienced with five-unit teletype codes. The Admiralty Research Establishment has successfully developed a special slow-speed modem using ASCII with frequency and time diversity combined with an intelligent detection and decoding algorithm. This is claimed to provide reliable HF communication under conditions that would previously have required a fall-back to morse. It uses ten 100-baud tones in a 3kHz band to provide a data rate of just 10 bit/second. But such a modem is a long way from the type of HF packet networks now coming into use on a variety of professional and military networks as well as by radio amateurs. For amateurs at least, AMTOR with baudot teleprinter code rather than packet with ASCII seems the logical choice for HF for those no longer satisfied with morse.

RF Connections are by Pat Hawker

its constraints in terms of the number of wires and segments available".

One aspect of his investigation of Yagi antennas should be of particular interest, to both professionals and radio amateurs. For many years one of the standard references used when building high-gain, long-boom VHF/UHF Yagi arrays has been a 20-page, 1976 publication of the US Department of Commerce and National Bureau of Standards (NBS Technical Note 688, "Yagi Antenna Design" by Peter P. Viezbicke), based on experimental measurements made on a 400MHz antenna while optimizing designs. Viezbicke attempted to show (a) the effect of radiator spacing on the gain of a dipole; (b) the effect of different equal-length directors, their spacing and number on realizable gain; (c) the effect of different diameters and lengths of directors on realizable gain; (d) the effect of the size of a supporting boom on the optimum length of parasitic elements; (e) the effect of spacing and stacking of antennas on gain; and (f) measured radiation patterns of different Yagi configurations.

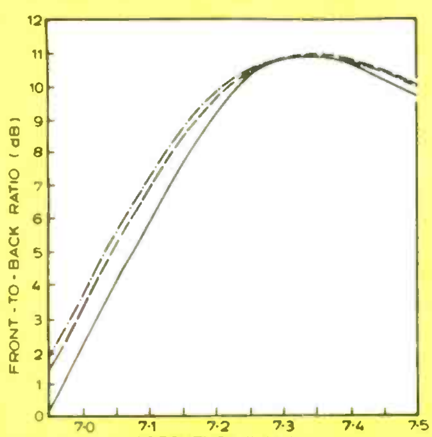


Fig.3. Front-to-back radio of the Yagi-Uda array: Lawson (solid line), Mininec (broken line) and Pozar (dots and dashes).

This monumental work has deservedly influenced antenna design during the past decade and has much improved the results achieved with such long-boom, multi-element antennas. But I recall that after I had published a short summary of the NBS study, Les Moxon, G6XN and formerly of Admiralty Research, although reluctant to criticize another author's work, was moved to suggest that "Peter Viezbicke has failed to ask himself the two basic questions that should always be considered when presenting such findings: (1) do the results make sense?; and (2) are they consistent with previous work, and if not, why not?".

He was particularly concerned about two of the basic findings derived from the 400MHz antennas: "For a dipole with simple single-rod-type reflector, Viezbicke puts the optimum gain as only 2.6dBd (i.e. 4.7dBi) with an increase of an extra 0.75dB to 3.35dBd with a considerably more elaborate trigonal reflector. Then with the addition of just one director (using the trigonal reflector), *wham*, the gain shoots up to 7.1dBd. The third element thus appears to be capable of providing an extra 3.75dB of forward gain".

Les Moxon pointed out that if Viezbicke's findings could be substantiated they would provide an overwhelmingly strong argument in favour of using three-element rather than two-element HF Yagi arrays. He added, however: "Real life just isn't like this. Curves in the ARRL Antenna Book and elsewhere based on the classic 1937 paper by Dr George Brown show gains in excess of 5dBd for a dipole plus reflector, and I have repeated the calculations myself many times, obtaining figures in the region of 5.2 to 5.4dBd depending on the particular source of data on mutual impedance". In practical designs, he suggested, it seems possible to achieve about 5dBd (7.1dBi) forward gain from just two elements but only roughly 6dBd from three elements.

In his ICAP paper, Dr Austin compares his computer results using Mininec and Pozar computer codes with Peter Viezbicke's data and also with that of J.L. Lawson ("Yagi Antenna Design", ARRL, 1986). **Figure 1** shows the effect of reflector-to-radiator spacing on array gain and underlines how closely the computer results agree with classic theory yet differ significantly from those obtained by Viezbicke on the antenna range. A startling validation of microcomputer antenna codes!

BROADCASTING

Helix antennas for user-friendly FM

For much of the past decade the BBC has been seeking to increase the use by listeners of its VHF/FM services by making reception easier with user-friendly FM sets. Indeed, the introduction of RDS is one aspect of this policy, although imposing a significant cost penalty on listeners. Some years ago the BBC tried, with little noticeable success, to increase the popularity of FM listening by designing and offering to industry a portable receiver with push-button tuning and an active ferrite-rod antenna* (with pre-amplifier) in place of the awkward, and sometimes dangerous, telescopic rod. This design had little impact on an industry in which British production had sunk almost out of sight.

With the proposed ending of duplication of programmes on VHF and medium- and long-wave stations, the BBC has been renewing its efforts by taking another look at user-friendly antennas for portable FM receivers. Using a large TEM cell of the type now used for checking the immunity of receivers to local RF fields, BBC Research has assessed the characteristics and practicality of five different types of antennas suitable for use with portable FM receivers.

R.D.C. Thoday (IEE Conference Publication No 301 (ICAP89), Part 1, pages 502-6) compares the characteristics of (1) the quarter-wave whip, (2), the short whip, (3) the ferrite antenna, (4) the frame antenna, and (5) the normal-mode helix antenna. His results are summarized in the table. He concludes that the helix is "a very strong contender as the ideal antenna for the portable receiver".

He shows that reasonably good reception can be achieved in a domestic environment using a compact helix which can be compact, robust and does not need to be accurately tuned. While the quarter-wave whip provides the most sensitive antenna for this application, the convenience of the helix, particularly in its more flexible forms, makes it more suitable. The addition of metal foil to form a ground plane on the inside walls of the receiver cabinet is recommended, to improve the performance of both the whip or helix antenna.

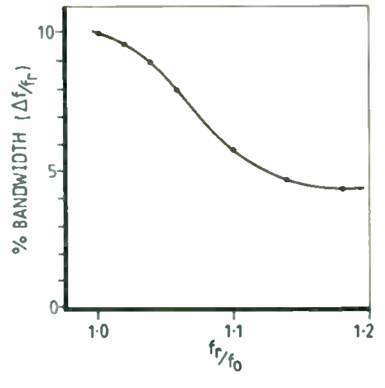
The short normal-mode helix, comprising roughly a half-wavelength of wire wound on a suitable former and resonating as a quarter-wave antenna, is widely used for hand-held transceivers, in amateur practice often termed the "rubber duck" antenna.

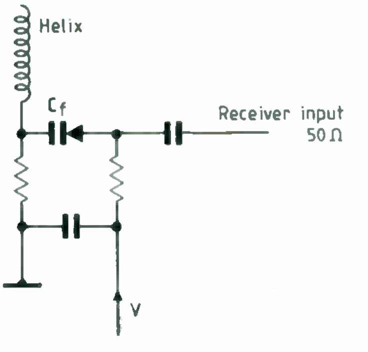
BBC Research has also investigated the attenuation of VHF signals within a domestic (building) environment relative to the RF field at the standard height of 10 metres outside the building. It was found that the building loss is of the order of 13.6dB with a standard deviation of 7.5dB for vertically polarized Band II signals and 16.7dB (standard deviation 6.7dB) for horizontally polarized signals.

Characteristics of antennas for portable FM receivers

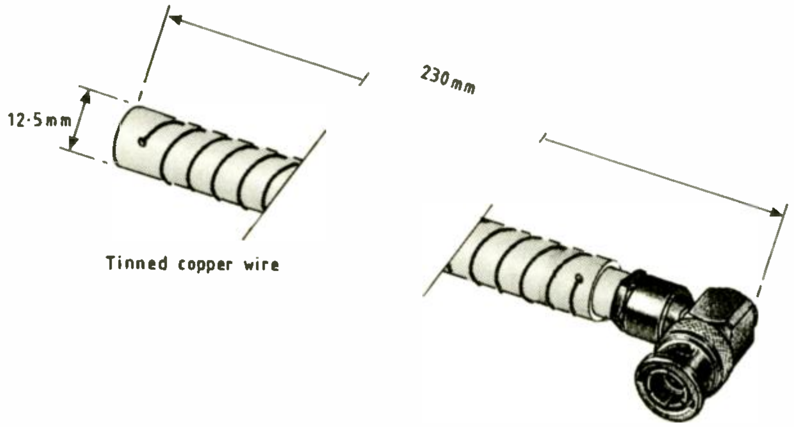
	Quarter-wave whip	Short whip[1]	Ferrite	Frame[2]	Helix[3]
Sensitivity (ref. ½λ dipole)	−3dB	−25dB	−23dB	−22dB	−10dB
Bandwidth (3dB)	broad	broad	3.2MHz	2.0MHz	9MHz
Tuning required?	no	no	yes	yes	yes
Cost	low	low	high	moderate	moderate
Convenience	Awkward, can injure user	compact	compact, fragile need to avoid shock and strong magnetic fields. Accurate tracking with receiver tuning.	compact, not easily rotated, needs accurate tracking.	compact, robust, can be made flexible. Does not need accurate tracking.
Mounting	outside cabinet	outside cabinet	inside or outside cabinet	outside cabinet	outside cabinet

Notes
1. Short whip about 260mm long.
2. Sensitivity depends on circuit Q, governed by skin effect and tuning capacitor losses. With single-turn, thick-conductor loop, Q may be larger than necessary, making tracking difficult.
3. Without tuning, a helix resonated to the centre of Band II will show a further 10dB loss of sensitivity at band edges.



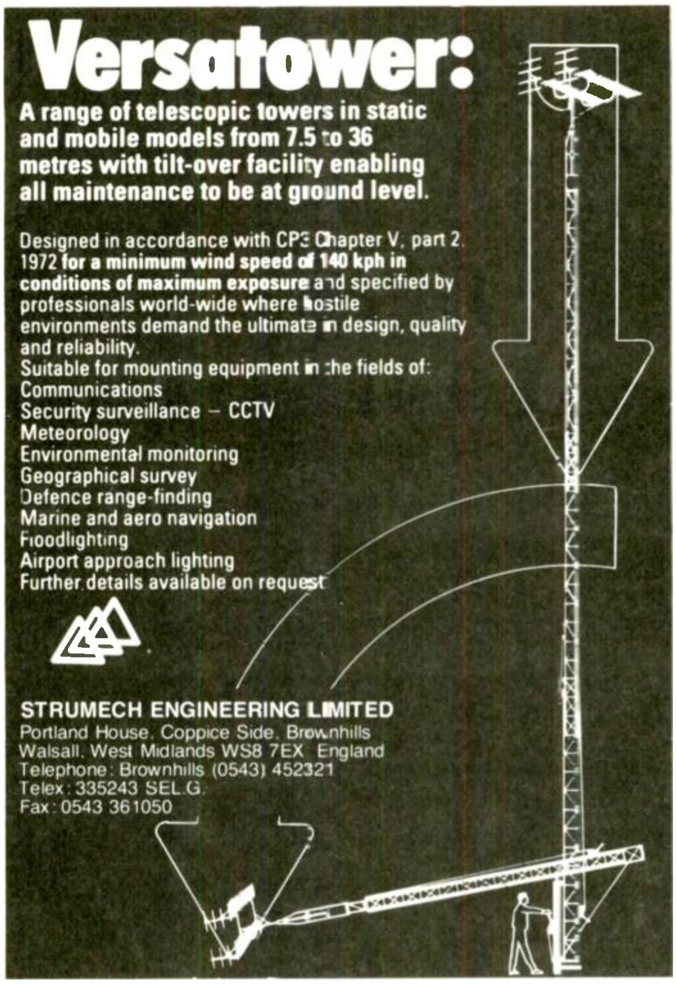


Variation of bandwidth with tuned frequency for a helical antenna, above its natural resonance.



Experimental normal-mode helix antenna for portable VHF/FM receivers (BBC Research).

*See Band II ferrite aerial unit, by R.D.C. Thoday, *Wireless World* September 1977, 47-48.



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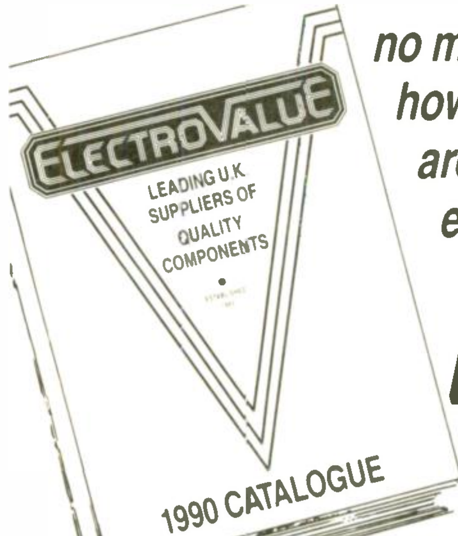

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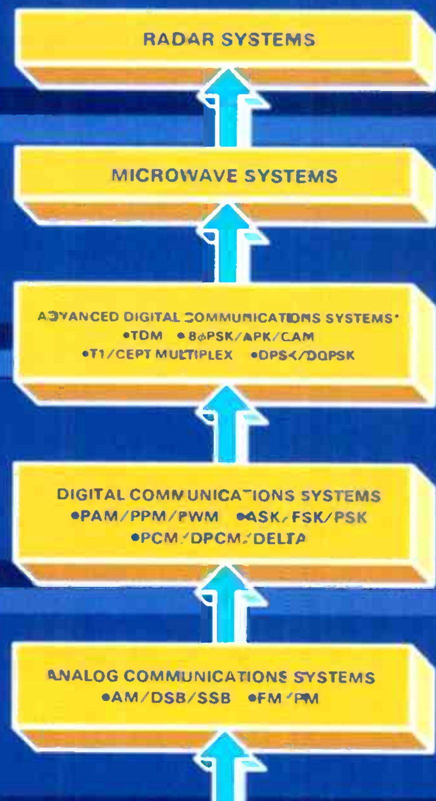

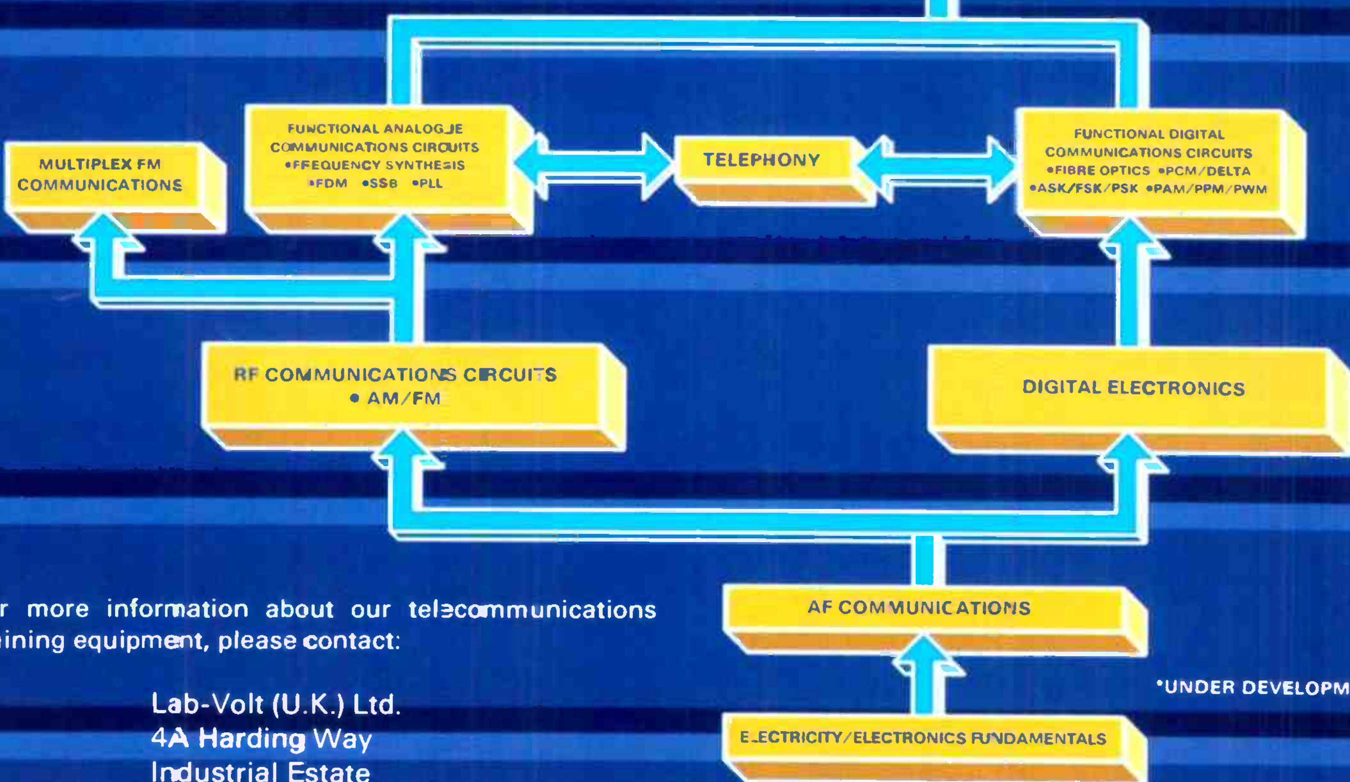

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FM Sound Sub-Carrier	— 6MHz (available 5.5MHz)
Modulation	— Negative
IF Vision	— 38.9MHz
IF Sound	— 32.9MHz (available 33.4MHz)
Sound Pre-Emphasis	— 50us
Ripple on IF Saw Filter	— .6dB
Output (any channel 47-860MHz)	— +6dBmV (2mV) 75 Ohm
Vision to Sound Power Ratio	— 10 to 1
Intermodulation	— Equal or less than 60dB
Spurious Harmonic Output	— −40dB (80dB if fitted with TCFL1 filter or combined via TCFL4 Combiner/Leveller

CCIR/3-1	— Specification as above but output level 60dBmV 1000mV Intermodulation 54dB
Other Options Available	— I.F. Loop/Stereo Sound/Higher Power Output
Alternative Applications	— CCTV Surveillance up to 100 TV channels down one coax, telemetry camera control signals, transmitted in the same coax in the reverse direction

802 DEMODULATOR SPECIFICATION	
Frequency Range	— 45-290MHz, 470-860MHz
A.F.C. Control	— +/− 1.8 MHz
Video Output	— 1V 75 Ohm
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Tunable by internal preset
Available for PAL System I or BG

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Output	— 6dBmV (2mV) 470-860MHz
Modulation	— Negative
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Double Sideband Modulator(unwanted sideband can be suppressed using TCFL4 Combiner/Leveller)

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to combine outputs of modulators

TCFL2	2 Channel Filter/Combiner/Leveller. Insertion loss 3.5dB
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