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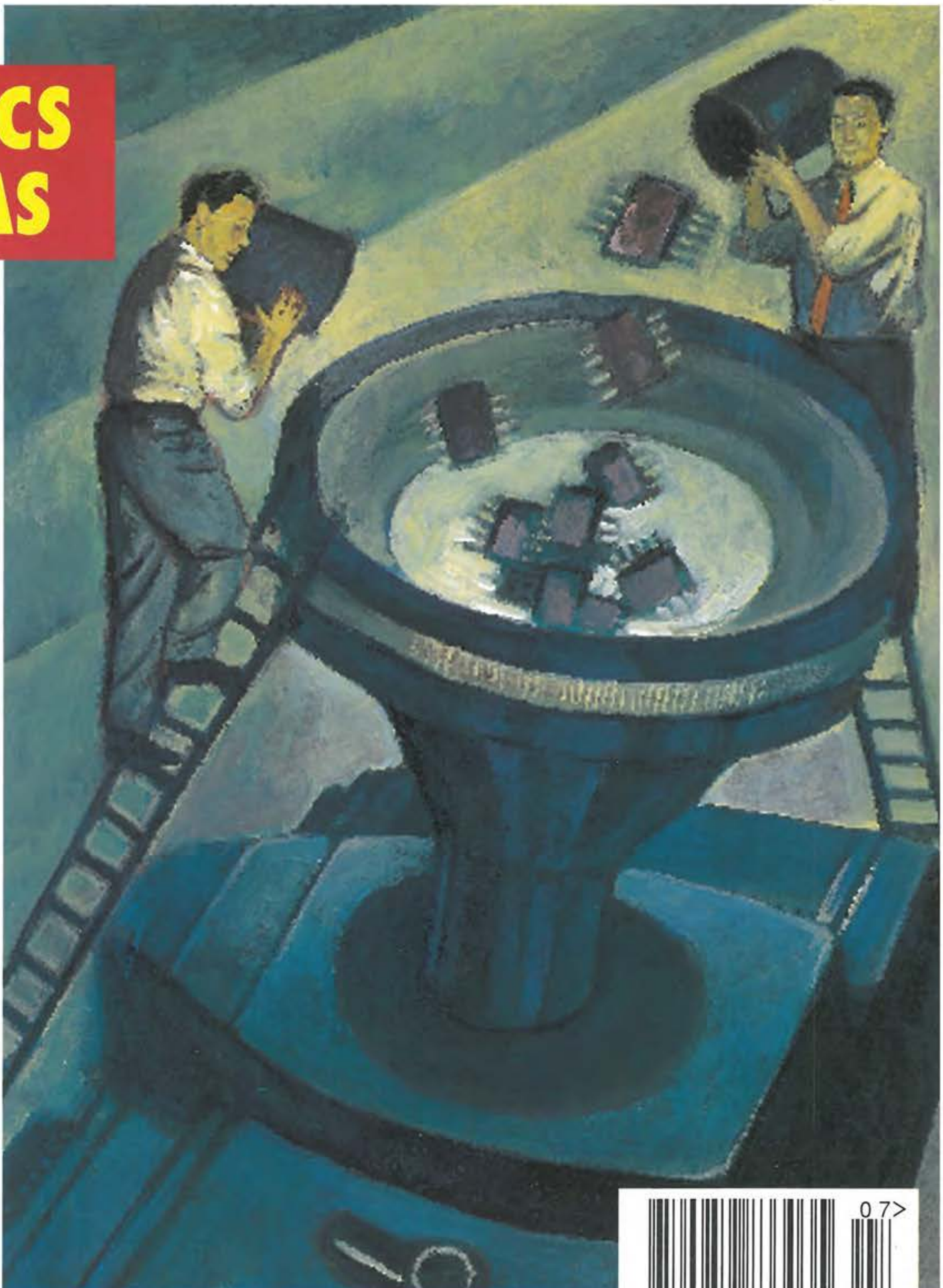

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PC Engineering: *Workbench EDA* reviewed

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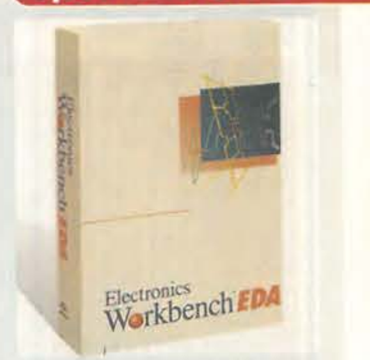

To celebrate the launch of Electronics Workbench EDA, Adept is offering readers an exclusive introductory discount – turn to page 553.

50% reader discount. A step up from the two-way wireless data link, this uhf module includes packet switching – see page 613.

Researchers at Rochester University have produced a polymer led that can shine any colour from red to blue – see page 540.

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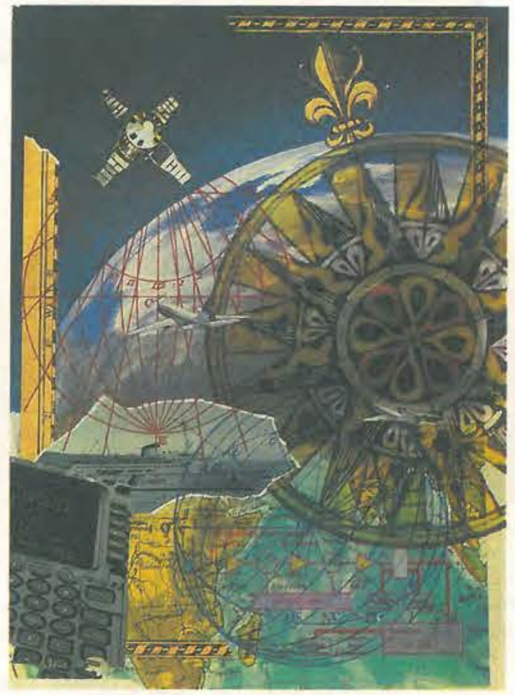
A century of invention?



Could GPS be the invention of the Century?

If you had asked people fifty, or even perhaps ten years ago, what was the Twentieth Century's defining contribution to civilisation, most would have unhesitatingly nominated the internal combustion engine. A few brave souls might have proposed the wireless or the telephone, if not discouraged by the difficulty of deciding between them. One or two might have suggested television, risking the correction that it is only wireless carrying a particular type of information.

Actually, all of these except for television were born in the last century, though it took this century to develop their full potential. It is fairly obvious now, that – visible and pervasive as cars and aeroplanes are – the thing which has really shrunk distances in the world, and touched and changed all our lives; the achievement which has crowned and pervaded every aspect of twentieth century technology, is the computer.

So it seems odd that the most significant contribution to the marking of the millennium thus far devised by the computer and electronics community is an act of collective hara-kiri as mainframes the world over seize up when asked to roll the year over from 99 to 00.

Admittedly it could be spectacular, and will be if nothing is done. Urban mythology is already rich with tales of prematurely-condemned corned-beef presumed to be 100 years old, and life assurance customers which the computer cannot believe will still be alive in 2005. The image of the party to end all parties grinding to a halt as aeroplanes are grounded, bank accounts mysteriously empty and systems everywhere switch themselves off has a rich, Sharpean irony. As a tribute to humanity's cosmic lack of foresight and capacity to cock things up, it could hardly be bettered.

Unfortunately, it probably won't happen. Even the doziest corporation must by now have asked its IT department to look into things and hire some programmers if need be.

So what else can we suggest as the electronic community's contribution to millennial celebrations? What would make a decent digital equivalent to planting a line of trees along the Greenwich Meridian, or freezing the Thames, or even just dancing in the streets?

The trouble with most forms of electronic communication is that they do not readily lend themselves to large or permanent public monuments. They are either a means to an end, like television, or essentially small-scale and private.

There is no way that visiting a website, however many people do it, can be turned into a grand gesture. Nor is the answer to be found in giant banks of computer screens, as at Berlin and other big trade shows. Grandiose perhaps. Meaningful, no.

What we need is some imaginative idea which will mean something to people, which they can see or be touched by, and which they will be interested in. If you are expecting me to spring a master plan on you that meets these requirements, then I'm afraid you will be disappointed. I simply want to start people thinking, or maybe to hear about thoughts which people have already had.

What I can suggest are a few elements which such a project might include. Since the millennium is about time, inseparable in our thinking from space, my own feeling is that the focus of any project should involve navigation and/or communication.

Navigation means Harrison's chronometer (that being when it started to get accurate) and GPS – which may or may not be working at 00.01 on 1 January in the year 2000. Communication leads inevitably via wireless and telephony to the Internet, the sprawling, invisible 'virtual' equivalent of trade-routes, postal services, broadcast systems and gossip-shops. By 2000, it's estimated that 700 million people will be connected to the net – about a dozen times the present number

You could argue that the Internet is itself the ultimate monument to electronic communications, and – in its informality – to humanity's ingenuity and instinct for co-operation. But an everyday tool cannot be in itself a celebratory gesture, though it might be the inspiration for one.

We need something grand, compelling, imaginative and – as is the way with the best monuments – pointless in a magnificent sort of way.

Any suggestions? E-mail me at
101460.115@compuserve.com or
martin.eccles@rbi.co.uk. ■

Peter Willis

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UP DATE

A twinkle in the cat's eye

The use of active road studs is a step nearer following the completion of road trials on the A1 and M50.

Road studs, of which cat's eyes are the most famous example, are passive reflecting devices. The Doncaster-based company, Astucia, is promoting a version which, in addition to a passive reflector, uses leds and a solar charged battery.

"Both trials were to test the studs in their passive state for survival and reflectivity, but we fitted the M50 ones with infra-red leds which were still operating at the end, after 12 months on the road," said Tim Lane, a spokesman for Astucia.

The studs are self contained and can change behaviour in response to varying conditions. A variety of colours and flashing patterns are available and optional in-built sensors are claimed to allow the studs to respond to ice, fog, standing water, standing vehicles and vehicles driving too close together. Vehicle distance is measured based on the frequency of the passing headlights.

Active road testing should begin this autumn. Lane said: "Three sites have been identified in the Wakefield area. Providing there is money in the local budget, they will begin operation in September." The installation to be used in Wakefield provides continuous night time illumination visible from 800m.

Active eyes... Shown is the circuit board from the cats' eyes alternative.

FEI optimistic about new government

Cautious optimism is the response of the electronics industry to Labour's sweeping General Election victory.

The Federation of the Electronics Industry (FEI) expects the ending of 18 years of Conservative government to result in a renewed emphasis on training and encouragement of small high technology businesses. But it acknowledges the Social Chapter, to which Labour is committed, could reduce competitiveness.

Anthony Parish, director general of the FEI, qualified his welcome for many of Labour's industrial objectives by adding: "We are still waiting for them to fill in some of the detail."

Parish identifies education and small businesses as two areas where the new government will affect the electronics industry. "They will pursue the education issue with great vigour. They can make a major contribution there," he said. "And they'll have a more co-ordinated approach to the support of small businesses. The [Conservative's] Business Link programme hasn't evolved enough and it is not tied-in to other European programmes."

In the area of social policy, Parish warned that the Social Chapter could be detrimental to the UK's competitiveness, but that "the Minimum Wage will not be likely to affect inward investment decisions, provided it is set at a reasonable level".

Brian Haken, of the Printed Circuit Interconnection Federation, said: "Industry is looking for a pro-active stance towards Europe. What we don't want is the incoming government to be split down the middle, with Euro-enthusiasts on one side and Euro-sceptics on the other."

If the reaction of Racal Electronics is any indicator, electronics manufacturers have already come to terms with the prospect of a Labour government. "We do business with governments around the world representing the full political spectrum. We've worked with Labour governments in the past and look forward to doing so again," said Racal's spokesman, which has government contracts ranging from defence work to running the Government Data Network.

Wings at the speed of sound... A researcher from the Georgia Institute of Technology holds a prototype microflyer, with flapping wings, as part of its programme to develop reconnaissance aircraft with wing spans of less than 15cm. The aim is to make autonomous vehicles that can enter difficult spaces like collapsed buildings. Georgia's specialist area is sensors, and it is currently working on a television camera-radio transmitter combination which it hopes will weigh less than one gramme.

Pentium II arrives, as expected

Son of PentiumPro... Intel's Pentium II microprocessor which was launched London recently.

Intel's worst kept secret, the Pentium II processor, was officially launched in London during May.

Two processors versions with clock speeds of 233 and 266MHz, have been announced. Both are designed for use in desktop pcs and are priced at $636 and $775, respectively in 1000 unit quantities.

Over a dozen desktop systems using the Pentium II from several PC manufacturers have also been announced.

Intel's Pentium II is facing competition from Advanced Micro Devices' (AMD) K6 and Cyrix's M2 x86 microprocessors.

AMD's K6 is much cheaper than the Pentium II – the 233MHz K6 costing $469. However, Intel's selling price includes a 512kbyte level two cache.

Cyrix, meanwhile, has yet to launch its M2 device although this is expected later this quarter.

The 233MHz clock speed of the K6, limited by the use of a larger 0.35μm manufacturing process (Intel uses 0.28μm), has resulted in Intel regaining the crown for the highest clocked x86 processor. AMD's lead over the Pentium lasted a month only.

Using benchmarks to compare the two processors directly is difficult since AMD does not quote integer and floating point SPEC figures. However, from preliminary tests, the two devices, similarly clocked, appear to have comparable performance.

The Pentium II fares less well when compared to Digital's recently announced stripped down Alpha, the 21164PC. The Alpha for desktop pcs is priced at $495 for a 533MHz part. Digital claims a SPECint95 of 14.3 and SPECfp95 of 17. In contrast, the Pentium II manages only 10.8 and 6.9, respectively.

Intel plans to release a 300MHz workstation version of the Pentium II in the second half of the year, priced at $1981. This is believed to be code named Deschutes, a 0.25μm five layer metal shrink of Pentium II.

The current leading workstation processor, Digital's Alpha 21164, costs under $2000 for a 400MHz part. Intel's 300MHz Pentium II has a SPECint95 of 11.6, compared to 11.7 for the Alpha. Floating point, however, is a different story. Intel estimates 7.2 for SPECfp95, while the Alpha more than doubles that at 15.9.

Mobile phone cancer – more research needed

The National Radiological Protection Board (NRPB) has called for more research into the carcinogenic effects of mobile phones after an experiment demonstrating the cancerous effect of electromagnetic radiation on mice.

The study, performed over 18 months by a team of researchers in Australia involved two sets of cancer-prone mice. One set was subjected for an hour a day to electromagnetic fields similar to those emitted by mobile phones. The researchers found 43 per cent of mice in the exposed set developed cancer compared to 22 per cent in the non-exposed set.

According to the NRPB, the result of the study "emphasises the need for more high quality research to be carried out on the possible biological effects of high frequency electromagnetic fields".

But funding needs to be earmarked by the European Commission before organisations like the NRPB can put together research proposals, said Richard Saunders, group leader of the NRPB's Biological Effects Department. "It's now up to the European Commission to put out a call for further research," he said.

This will be done later this year according to Leo Koolen of the EC's telecommunications directorate DG13, who criticised the Australian experiment because of its use of cancer prone mice.

"It is very difficult to relate this kind of research, which uses genetically manipulated mice, to the real world," he said. "The question is: How representative are these tests? It is generally considered by experts that we must do research in the real world."

Memory module prices fall sharply

Prices for memory modules has dropped sharply as supply starts to outstrip demand in the pc market.

"We've seen evidence of increased spot market activity during April with oems off-loading product," Andrew Mackenzie, director of memory at Datrontech, told Electronics Weekly. "We're selling 16Mbyte simms out of the Far East at $67 duty unpaid."

According to d-ram price-trackers ICIS-LOR, the price of a 16Mbyte simm dropped $9 from $80 to $71 in late April. In the USA and Asia-Pacific, the dip is $6 to $71-$72. "We've heard of large distributors getting offers from some of the oems," James Hone of ICIS-LOR told *Electronics World*.

Demand for simms from the top tier pc producers is said to be firm, but lesser tier producers are reported to have cut back on requirements. Manufacturers are said to have two week's worth of simm inventory.

A top ten memory supplier told *EW* that the dip could be due to a move away from simms to dimms, and continuing excess of supply. Although device manufacturers, peripherals manufacturers and distributors are reluctant to state it publicly, they point in private to a weakening in pc demand as the main reason for the dumping of simms and the lower prices.

Web tv – who'll watch?

Internet boxes that turn a television into a World Wide Web browser, such as Microsoft's WebTV, will take several years to find a mass audience, says market research firm, Forrester Research. The company says that WebTV-type devices will only be in use in one million US households by the year 2000.

The reasons for the devices' slow sales is that there is a lack of compelling content, and limited overlap between Web content and TV programming. Internet screen phones will be more popular, claims Forrester, because they provide voice and data communications. As many as one million Internet screen phones could be in use by 1999.

Forrester based its predictions on interviews with large Website providers with more than three-quarters saying that they had no plans to adapt their content for WebTV or Internet screen phone devices.

Internet via satellite

Peter Willis reports on a newly announced Internet service that should solve the problem of slow data retrieval by using a satellite link.

The convergence of tv and computers is taking many forms as we enter the digital age. One of the most potentially fruitful is the delivery of Internet by satellite. It was the chief talking point of the recent Cable & Satellite show in London, in the continuing absence of the long awaited announcement from BSkyB of its digital tv services.

BSkyB it seems was hung up on convergence issues itself, trying to develop an interactive terminal with BT and and a banking partner (HSBC) while awaiting the outcome of its BDB consortium application for a digital terrestrial licence.

It is the sheer scope of the digital opportunity which is creating indigestion. Not that some people are waiting for digital tv. Pace Micro Technology, maker of satellite receivers both analogue and digital, is diversifying into low-cost Internet terminals through a link-up with US service provider Webtv. Now bought-out by Microsoft, Webtv has perfected user-friendly delivery of Web pages to ordinary tv sets, having first tidied-up the signal to create a decent picture on American NTSC sets.

But whether viewing on a tv screen with its coarser dot-pitch or a pc monitor, all Internet users experience the frustration of waiting for pages to download as the bit stream is funnelled into the constricted passageway of the telephone network – an antiquated, 19th-century information goat-track by comparison with with what is actually required for efficient delivery.

Down-load a cd's worth in 11 minutes

This is where satellite comes in. With no fixed-link wires to slow things down, satellites can download data faster than most pcs can swallow it. A cd rom can be downloaded in 11 minutes, compared to 23 hours over an ISDN phone line. Both Eutelsat and Astra are working on the idea, but don't rush to plug your 60cm dish into your desktop multimedia pc. The emphasis at present is on business or institutional use.

Eutelsat is already handling a number of not-quite-net services, including Net on Air, which provides selected bundled pages, and DirecPC, operated by Hughes Olivetti Telecom chiefly handling large volumes of data for businesses. Others are Tenfore, which specialises in financial data, HS-Cast (on-line newspapers).

Eutelsat is looking for a service provider partner to further develop the concept. Astra meanwhile has joined with Intel to set up ESM (European Satellite Multimedia Services) and plans to have it working, under the name AstraNet by the end of the year. It too is looking at the corporate market first, concentrating on one-way, point-to-multipoint data broadcasting.

Options for return path data

Internet is of course a two-way concept, and there are two ways of creating the return path or back channel. The expensive way is to add a small transmitter to the satellite dish, as already used by V-sat technology. Astra doesn't expect to have the technology for this ready before the end of next year.

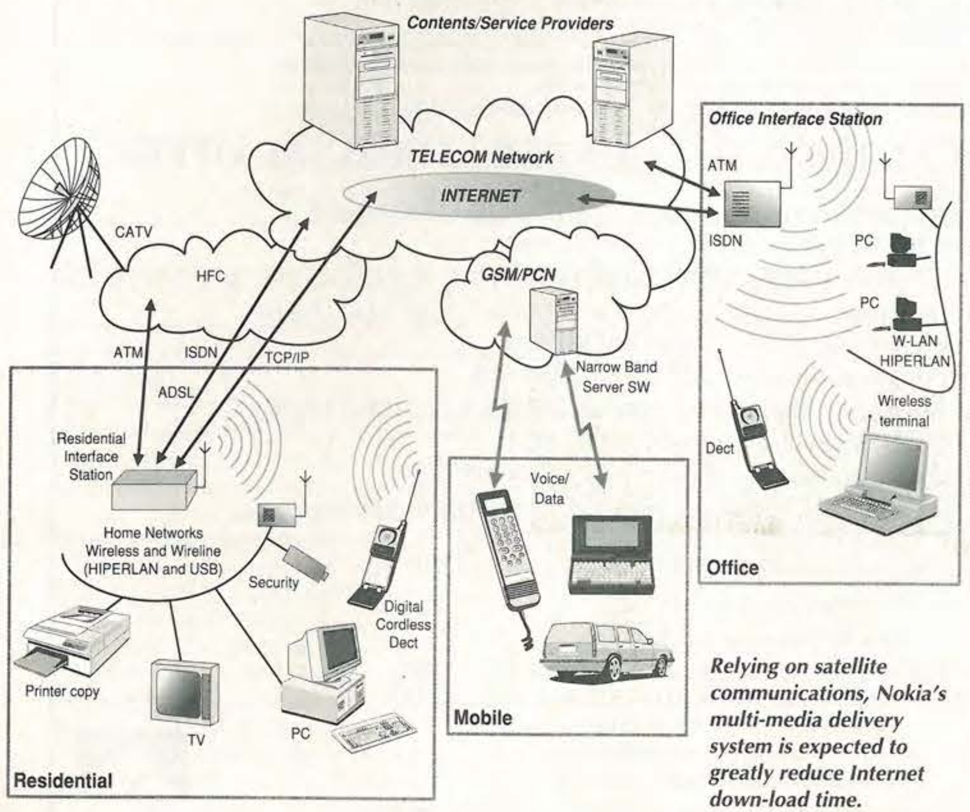
The easy way is to use the phone line. For most users this will be quite sufficient since they are typically recipients rather than publishers of Web pages. Their outgoing messages tend to be brief requests for information.

One indicator that the technology is eventually destined for consumer application is its compatibility, in AstraNet's case, with the DVB (Digital Video Broadcasting) standard.

Already, the requisite hardware is becoming available. Pace has teamed up with Hitachi to develop a satellite pc card, capable of pulling in data, video and audio at up to 38Mbit/s.

Nokia used the Cable & Satellite show to demonstrate its Home Browser multimedia terminal. As well as being a DVB receiver, this terminal handles World Wide Web and other forms of data, including e-mail and GSM Short Message Service, delivered via phone lines (regular and ISDN), cable and satellite. For good measure, it will also cope with inputs from in-home systems such as a pc or security cameras. Outputs can be to tv, PC, printer or modem.

Described by Nokia as a 'gateway terminal,' the unit uses flash memory instead of rom. Based on a modular architecture, it is part of the company's Mediamaster family of terminals. The first of these, designed to pick up free-to-air digital satellite transmissions (at present only from some continental stations) has just gone on sale in the UK at £529.99. ■



Relying on satellite communications, Nokia's multi-media delivery system is expected to greatly reduce Internet down-load time.

RESEARCH NOTES

Jonathan Campbell

Room temperature quantum material is bathed in gold

Gold-cluster molecules, possessing a set of extraordinary quantum properties, could form the building blocks for testing ultra miniaturised architectures envisioned by some for 21st-century nanoelectronics, according to researchers at Georgia Tech in Atlanta. Their main fascination is that their conduction electrons are quantised both in their number and in the states they can occupy. Normally, such effects can only be observed and used at very low temperatures – such as that of liquid helium, near absolute zero. But the Georgia Tech team reports that the new series of nanocrystals are both sufficiently small that these effects are prominent even at ordinary temperatures, and yet are large enough to have the robust crystalline properties of the bulk metal.

In structure, each molecule in the new series has a compact, crystalline gold core – just 1-2nm across – encapsulated within a shell of tightly packed hydrocarbon chains linked to the core via sulphur atoms.

"The surrounding chains can be of any length, and can be modified to confer particular chemical properties, so that they can be incorporated into various solid-state and solution structures," says professor Robert Whetten, head of Physics and Chemistry at Georgia Tech. "Most importantly, each member of the series behaves as a substance composed of infinitely replicated molecules, which can be separated from other members of the series to yield pure substances with precisely defined properties."

The gold cluster molecules emerge spontaneously during the decomposition of certain gold-thiolate polymers of the type commonly used in decorative gold paints and in gold anti-arthritis drugs. With sufficient control of the decomposition process, this series can be isolated without concurrent production of larger gold crystals. It is then relatively easy to separate the principal members of the series from each other to obtain the necessary homogeneity. Once purified, the molecules spontaneously assemble into crystalline thin films, powders, or macrocrystals, while preserving the discrete properties of the individual gold nanocrystal cores.

Gold is important technically not only for its inertness – once made, the clusters are immune to corrosion – but also for its highly stable surfaces that find application as junctions in critical microelectronic applications. The electromagnetic and conduction properties of the clusters are extremely sensitive to charging, and somewhat less so to energy level. According to Whetten, this could allow them to be used in proposed electronic circuitry known as "single-electronics."

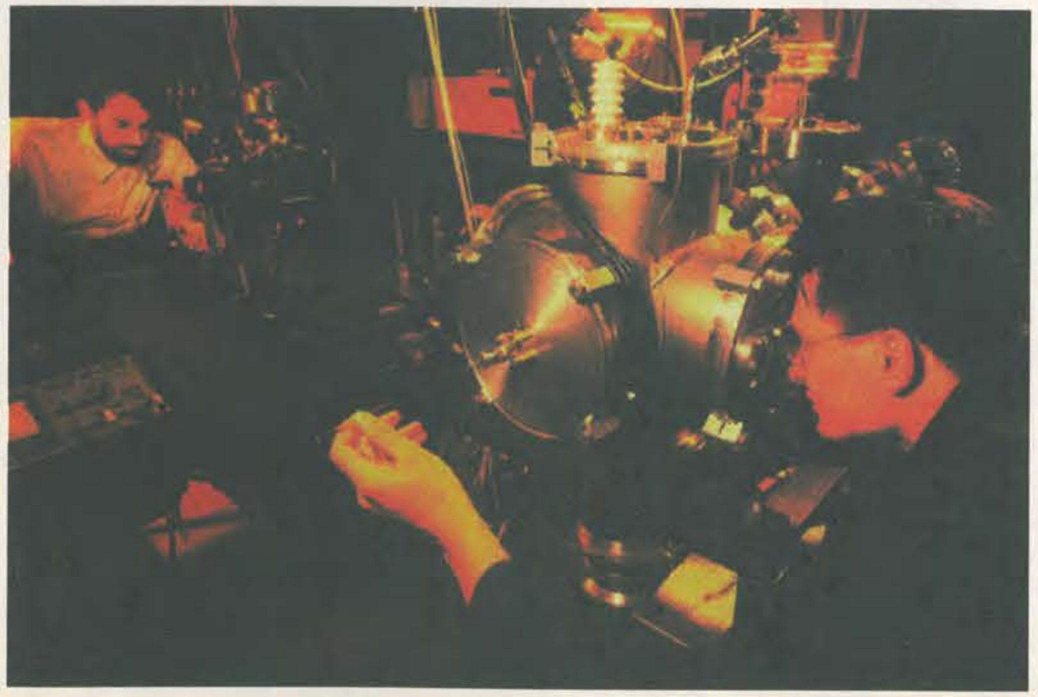
The new gold cluster materials are the first to exhibit charge-quantisation in a macroscopically obtained material, for which every cluster behaves identically. First measurements were conducted at Georgia Tech by observing the step-like changes in the current passing from a scanning tunnelling microscope tip to a gold plate through a single gold cluster molecule as the voltage was increased.

The highly regular spacing between these steps, known as the "Coulomb staircase," showed that the molecules' gold core is charging like a small metal sphere in a series of discrete steps by adding or removing single electrons.

Whetten and collaborators at the University of North Carolina-Chapel Hill have reported developing an electrode based on the most massive of the new series and have stared investigating electrochemistry.

Quantisation of the energy levels of the conduction electrons has also been observed separately in optical spectroscopy experiments that reveal the discrete level structure – even at room temperature.

New highly-stable gold-cluster molecules being developed at Georgia Tech could open up the world of nanoelectronics.



More information contact: Robert Whetten, 223 Centennial Research Building , Georgia Institute of Technology , Atlanta, Georgia 30332-0828, USA. email: robert.whetten@physics.gatech.edu

Sitting on fuel cell technology

Daimler-Benz's Necar II runs on hydrogen-oxygen technology but can still seat six people.

Fuel cell technology, able to generate energy from hydrogen and oxygen, offers several advantages as the drive system of the future in terms of cleaner vehicles and reduced reliance on fossil fuels.

Unfortunately, up to now, systems have been bulky and only useable in substantially modified vehicles. But Daimler-Benz has announced that its latest experimental vehicle manages to pack all the extra hardware required under the seat of a standard model.

Necar I, Daimler-Benz first experimental vehicle, demonstrated back in 1994 that fuel cell technology technology is a viable proposition. But it was hardly practical then, as the system had such high space requirements that it was more closely related to a mobile laboratory than a vehicle.

However, in Necar II, the scientists have reduced the size of the fuel system to such an extent that it can now be easily accommodated under the rear seat bench of a Mercedes V-class vehicle.

The compaction has been achieved largely by means of a drastic reduction in the thickness, through optimisation of their surface characteristics, of the bipolar plates that ensure an even distribution of the reactant gases to the electrodes. This has allowed the individual cells in Necar II to be grouped much more densely into stacks.

Furthermore, a new stack compression strategy has reduced the number of tie rods needed, making for considerable space savings. In Necar I the electrical and liquid supply connections were located separately. But in Necar II, the researchers have been able to unite them on the end plates thanks to a special compression technique and the use of new materials.

The moisturising units formerly required on each fuel cell stack have also been replaced by a single compact unit, separately located within the cell system.

All these individual measures combine to reduce the size of the system to such an extent that the laboratory on wheels of Necar I has now been transformed into the spacious passenger car Necar II, in which all six seats are available for passengers.

At present, the gaseous hydrogen required for energy production is still stored in tanks under the roof. Daimler-Benz research work is now concentrating on development of a system capable of deriving hydrogen from liquid methanol. This could make it possible to refuel a fuel-cell car using by using simple filling procedures not that different to those found in a petrol station of today.

Sensor that keeps war going could save lives too

Intensive-care patients in hospitals, infants at risk of suffering sudden infant death syndrome, and police, fire-fighting and construction personnel in hazardous situations could all benefit from a new telesensor being developed by the US military. The chip, designed to be attached to the fingertip or ear, is actually being being developed to get wounded soldiers back into battle as quickly as possible. But researchers believe it could be modified to provide valuable information on the physiological condition of patients in non-military situations.

The medical telesensors – application-specific integrated circuits that measure vital signs, process the data and transmit it as radio signals to a remote receiver – are being developed at the Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) for military troops in combat zones. Using funding from the Defense Sciences Office of the Defense Advanced Research Projects Agency (Darpa), a group led by ORNL researcher Tom Ferrell has built a 2.3mm temperature sensor. Attached to a finger or ear, the chip can measure body temperature and transmit a reading when queried by a remote receiver.

"Military leaders need a way to find out quickly which soldiers have been wounded and what their conditions are," Ferrell says. "Then, medics will be able to decide whom to treat first and whom to remove from the battlefield for treatment at hospitals. The first objective is to get the least seriously injured treated so they can return to combat."

The chip contains a temperature sensor that measures absolute temperature using bipolar transistors whose electronic properties are sensitive to temperature. These components are all incorporated on a single chip together with analogue signal processing, transmission electronics and an antenna that sends the data by radio signals (radio frequency transmission) to a monitor when the chip is queried.

Each chip, Ferrell says, is planned to have a unique identifier – a characteristic radio signal pattern in which the frequency spectrum changes every few microseconds. Such spread-spectrum transmission allows the monitor to know which soldier needs immediate medical care. In addition, newly-developed thin-film lithium-ion batteries could be used to supply the very low levels of power required by the circuit.

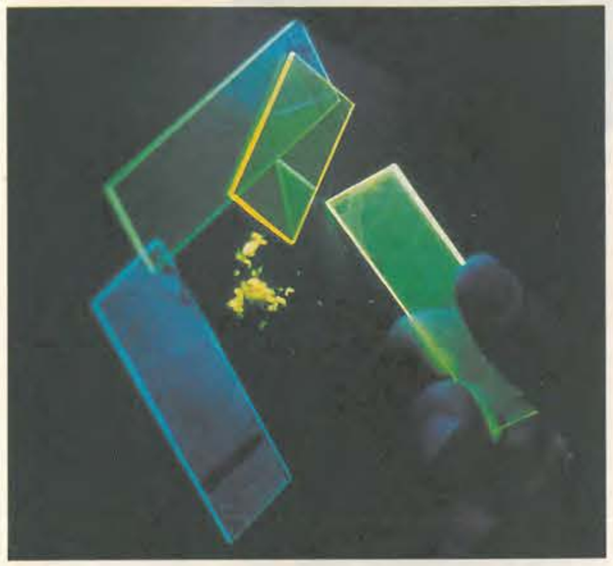
The ORNL group, which also has collaborated with several faculty members from the University of Tennessee, is now developing a pulse oximetry sensor. This device, ultimately to be fabricated on a single chip, will measure pulse rate and blood oxygen level. The group also plans to develop another type of pulse sensor and a blood pressure sensor, in addition to a device that measures electrical conductivity in the skin, an indicator of stress.

The pulse oximetry sensor will measure the pulse on the wrist or neck by use of an optical pressure sensor. To measure changes in blood oxygen level, the sensor detects changes in heamoglobin, the iron-containing pigment in red blood cells. When the oxygen level changes, the colour of the heamoglobin is altered. Such a chip will have an infrared light source and detector that can measure changes in the light absorption of the heamoglobin when it is excited by light of specific frequencies. Measurement results will all be reported by wireless telemetry.

More information contact: Tom Ferrell, Oak Ridge National Laboratory, Tennessee, USA

Polymer diode can switch on any colour

Polymer thin films, seen here under UV light, could form the basis of a new generation of led computer screens and televisions – or even traffic lights.



Computer screens, television monitors, fluorescent lighting and even traffic lights made out of low cost leds could be just round the corner following announcement of the first plastic device able to emit light of multiple colours. Unlike conventional leds, the new devices – made out of polyphenylenevinylene and polyquinoline – emit colours ranging from red to yellow to green and even blue, depending on the voltage applied to them.

Normal leds, made of materials such as gallium nitride or gallium arsenide, are limited to single colours, making them impracticable for the biggest application of all in flat-panel computer and television screens.

"The holy grail of the whole field of led design is a flat-panel display for use in future television screens and computer monitors," says Samson Jenekhe, a professor of chemical engineering, chemistry, and materials science at Rochester.

Jenekhe's multi-colour polymers raise the prospect of replacing today's bulky screens with much thinner and more efficient arrays of leds, and are said to outshine the performance of traditional materials in several ways. Most importantly, just one layer of the devices can create full-colour images and, unlike normal leds, Jenekhe's devices can produce efficient greens and blues.

Other advantages include the fact that the plastic led requires just three volts for start-up and is at least as bright as a current television screen. Since these plastics can be made at room temperature, the leds should also be far cheaper to produce than conventional leds, which must be made at high temperatures.

Key to the work has been the team's efficiency in bringing together the electrons and electron holes that combine to produce the light. Jenekhe's group has been able to construct layers of polymers tens of nanometers thick and position them so that they supply a steady stream of electrons and holes.

Researchers have tried to make such leds before – and some have even succeeded in producing a device capable of emitting light. But this has only been of a single colour. The new leds emit the full range of colours, depending on the voltage applied to them. By combining the light from several plastic leds, Jenekhe has even produced white light that could form the basis for led-based fluorescent lighting.

Another attractive application being targeted by researchers is in traffic lights. A large, lightweight polymer led could replace the heavy, inefficient 120V white bulbs that glow behind the coloured glass covers of traffic lights everywhere. Because the leds consume so little electricity, this could result in substantial power savings.

Forces that could blow nanochips apart

As the tiny electric wires in computer chips grow ever smaller and the current they carry proportionately greater, the wires' atomic structure becomes increasingly prone to breakdown, causing gaps that could disable a chip or even an entire computer.

Now a team of materials scientists from Columbia University and IBM has measured the forces created as electric currents dislodge atoms from microwires – and found them to be massive.

The phenomenon, called electromigration, is not expected to cause failure in existing computers, but will undoubtedly present a mounting problem to chip designers and manufacturers, say the researchers – Slade Cargill, professor of materials science at Columbia's School of Engineering and Applied Science, and I Noyan, a research staff member with the Materials and Processing Science Group at IBM's TJ Watson Research Center.

"We have gone up in current density by an order of magnitude, and that's the problem," says Cargill.

To measure changes in the atomic structure of a wire as current flows through it, the researchers focused a fine beam of X-rays. They showed that one end of the wire, to about 15% of its length, was stripped of metal, and that a build- up of atoms at the other end caused large stresses – of as much as 340Mpa – that eventually damaged the wire and its insulation.

The electrons travel along the wire as current and also dislodge atoms of metal from their positions in the wire, carrying them along and depositing them further downstream. Rearranging atoms in this fashion can create gaps where atoms are removed and can also create local pressures where atoms pile up, squeezing metal out of the wire much like toothpaste from a leaking tube.

At the moment, moving a few thousand atoms will not affect wires millions of atoms in diameter. But in microelectronics, many wires are now less than 1μm in diameter, and moving thousands of atoms around can have far more dramatic effects.

Computer failures because of electromigration actually occurred in the1960s, before hardware engineers were fully aware of the problem. They solved it by using new combinations of metals, by limiting current and the wires' length, and by encapsulating circuits in rigid insulating materials.

But during the last 30 years, the size of microelectronic circuits has decreased by almost 40 times, while current in those circuits has decreased less rapidly, from the range of 10 to 50mA to about a tenth of that level now. As a result, current density has increased by a factor of ten.

Once microwires shrink to 0.25μm in diameter and smaller, chip designers will have to discover ways to limit current sent through such wires, or find other ways to counter electromigration.

"These problems can be solved by changing the configuration and metallurgy of the chip," says Noyan. "However, new solutions will have to be found for each generation of chips, since electromigration is like an allergy. It can be mitigated but never fully cured." ■

ILLUSTRATION HASHIM AKIB

Electronics in photography

Leslie Warwick has been investigating how electronics is helping improve today's still-photo cameras.

The introduction of electronics into single lens reflex cameras in the form of through-the-lens exposure metering in the sixties was derided by 'real' photographers. Now most slrs, including professional models, are completely reliant on electronics – even in manual override mode.

There are now trends towards interfacing cameras with computers and making it easier for photographs to be integrated into electronic media. A recent illustration of the trend towards interfacing is the Advanced Photo System, or APS. This standard is the first to allow recording of magnetic data and photographic images together on a single film. It was developed by five major photographic companies, namely Canon, Fuji, Kodak, Minolta and Nikon. Over fifty companies have now licenced the technology.

APS uses an all-plastic cartridge that holds not only the unexposed film but the processed film too, so it is never handled by the photographer. The photofinisher supplies an index print showing all exposures and their frame numbers.

The cartridge is dropped into the camera, used, then taken to the film processor for developing. There the film is detached and reattached, and finally taken to the photographic laboratory for prints to be made, still in its cartridge.

Symbols on one end of the cartridge indicate the state of the film inside. There are automatic checks to prevent double-exposure, and the reloading or reprocessing of already processed film. Additionally, the camera can detect the film's ISO speed and number of exposures from the data disc on the opposite end of the cartridge.

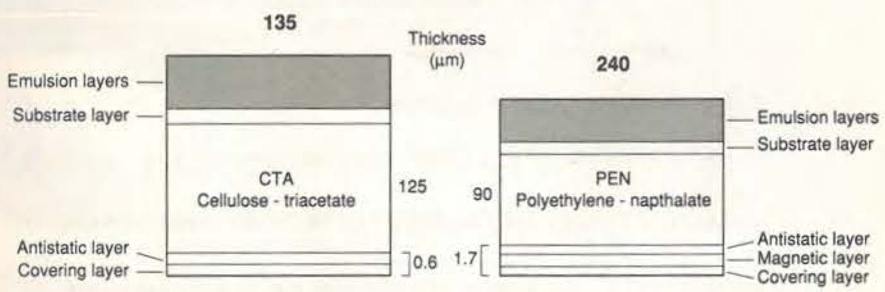


Fig. 1. Agfa's Advanced Photo System (240), or APS, and 35mm films compared. The magnetic layer allows recording of camera and photofinishing data. Thinner emulsion layers enhance sharpness by reducing light scattering in a frame size 40% smaller than 35mm. The new PEN base has better mechanical properties, helping to minimise damage when extracting and rewinding film from the cartridge. The film code, 240, indicates the film's width, of 24mm.

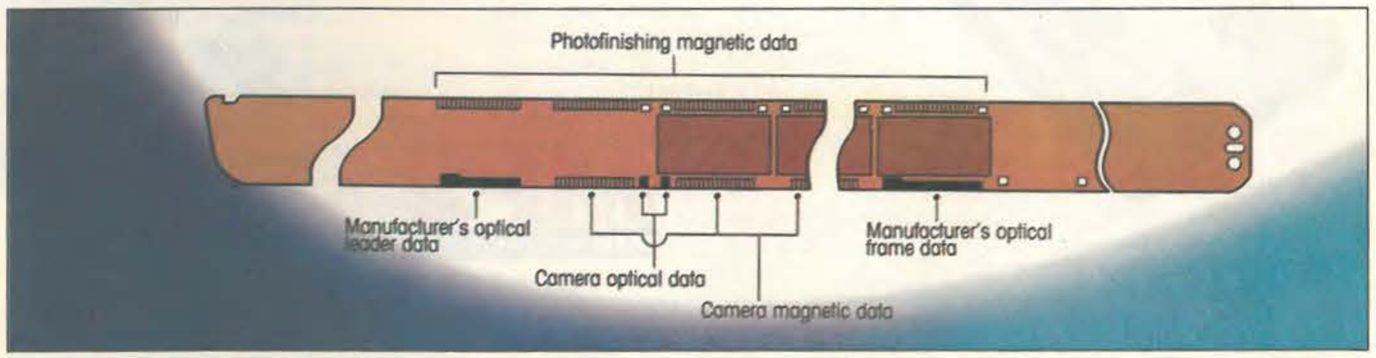


Fig. 2. The Advanced Photo System film has both magnetic and optical data tracks. These record the user's choice of print format, together with date and time, and shooting information such as flash and lighting data. Through Information Exchange (IX), this data is automatically read by photofinishing equipment and used for backprinting and optimising image quality.

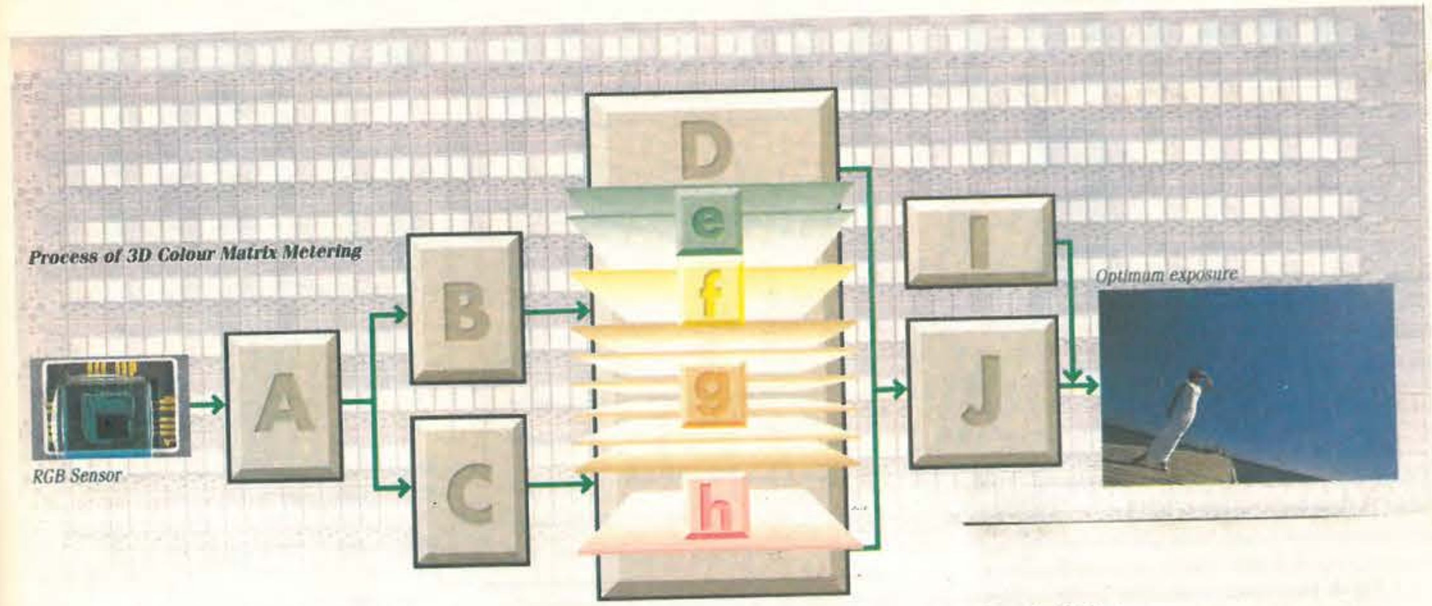
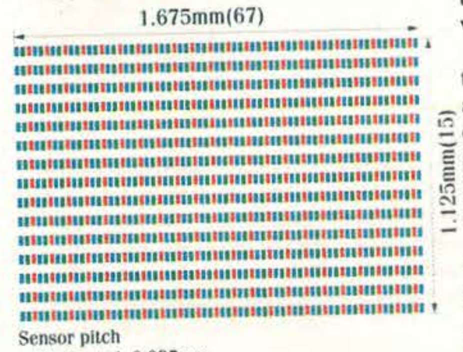


Fig. 3. Nikon F5 3D Colour Matrix Metering evaluates screen brightness and contrast by overlapped small group reading, together with selected focus area, distance information and colour for optimum exposure. Its advantages include the detection of poorly illuminated subjects and small subjects located at the periphery, the accurate evaluation of backlit subjects by overlapped small group reading and of course, the evaluation of colour.

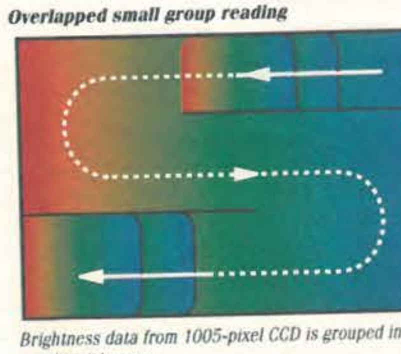
A. Brightness and colour data from 1,005 pixels
B. Colour data
C. Basic data (grouped into overlapped areas)
D. Parameters
e. Colour data
f. Average brightness data
g. Contrast data
h. Position of focus area selected
I. Distance Information (from D-type lenses)
J. Database

1005-pixel arrangement



Sensor pitch
Horizontal: 0.025mm
Vertical: 0.075mm

Overlapped small group reading



Brightness data from 1005-pixel CCD is grouped into overlapped areas.

APS film has a transparent magnetic coating across the full 23.95mm width of the film base, **Fig. 1**. However, recording is confined to tracks either side of the film, **Fig. 2**. Data relevant to individual frames, such as exposure information, are recorded beside the frames while data applicable to the whole film are recorded in the leader area.

One track is dedicated to camera data, the other to photo-finishing data. The signals are digital and, in the camera, are taken from a memory and recorded by a single head as the film is wound on. Optical data are also recorded by the film manufacturer and by the camera – the latter employing an orange led to produce a latent image of something similar to a barcode.

Cartridge and film identification numbers (CID and FID), in both human and machine readable forms, uniquely identify both for their rematching after processing. The CID is also reproduced on the index prints, and backprinted onto enlargements together with the frame number.

Photos on tv

A photo player has been conceived by Minolta and developed and manufactured by Fuji for displaying APS images on a television, or a computer with a video grabber. A fluorescent tube with radiation optimised to APS film illuminates the images, which are scanned by a line array ccd. Image sampling gives 1792 by 1024 pixels (640 by 480 for display) with 8-bit luminance and chrominance.

The negative data are then converted to positive video, with a horizontal resolution of approximately 430 lines, which is better than S-VHS. Facilities include an index display, exposure adjustment, altering the size and position of displayed frames, and an information display; there is even a 'slide show' function with background music. And it is possible to alter the IX data.

Fuji also has an APS image scanner for pc users. This has the same fluorescent tube, but a dual-line array scanner with 1030 pixels for both green and red/blue, producing a resolution of 1667 dots per inch for green and 834 dots per inch for red and blue together. Digitisation conversion accuracy is ten bits.

Fuji's EXIF, or exchangeable image file, format is used. Image data is recorded in uncompressed TIFF or compressed JPEG, with bit-map BMP format as an option.

Konica has a similar model; but this is additionally capable of scanning 35mm negatives and positives. Its maximum resolution is 1200 dots per inch. Professional film scanners are also being launched with APS facilities. Incidentally, positive APS film will be launched soon.

Photofinishers with a digital image workstation can copy APS or 35mm films, or prints, onto computer disks. Fuji's *Picture Plus* system offers floppy, zip and cd-rom storage. Again, this system employs EXIF, with BMP or PICT file format options.

Kodak's *Image Magic* system is based on the *FlashPix* file format developed by Kodak, Hewlett-Packard, Live Picture and Microsoft. It employs flexible compression and Microsoft's OLE structured storage. Images can be stored on floppy disk or cd rom. Both systems also provide decorative prints, postcards, etc – with Kodak additionally offering an Internet service for photo gifts.

Exposure meter for colour

Nikon's new flagship 35mm single-lens reflex camera, the *F5*, is the first to have an exposure meter that takes colour into account, **Fig. 3**. This employs a ccd with 1005 rgb pixels, located just above the eyepiece, where it takes light from the pentaprism. Brightness data with colour information is read from the rgb pixels, and the colour is extracted to calculate a signal that represents the average colour of the scene.

The brightness data is read in small groups which are moved up and overlapped as they

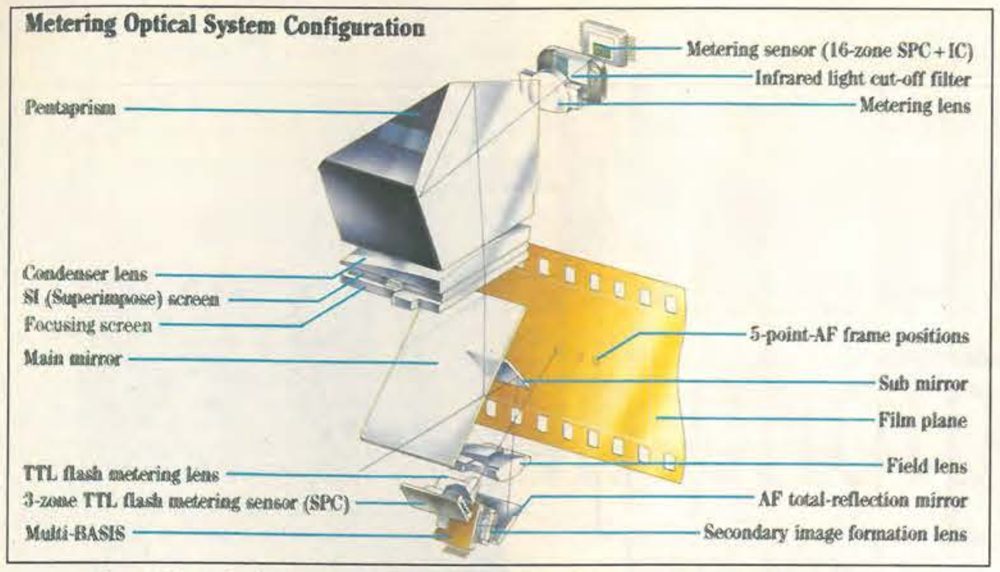
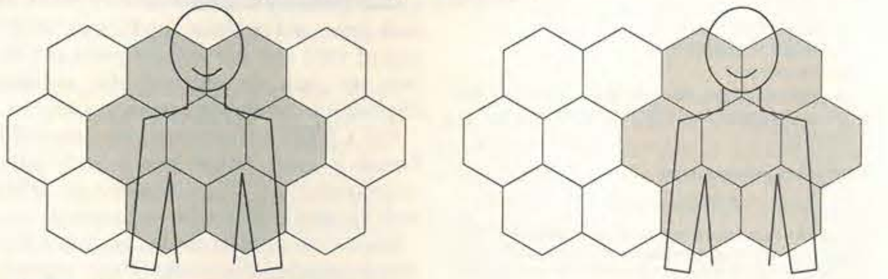


Fig. 4. The typical optical metering configuration of the Canon EOS-1N. Above the eyepiece and taking light from the pentaprism is the silicon photocell (SPC) exposure meter. In the base of the mirror box are the TTL flash metering SPC and the Multi-Basis (base stored image sensor) for autofocus – both taking light reflected by the sub-mirror.



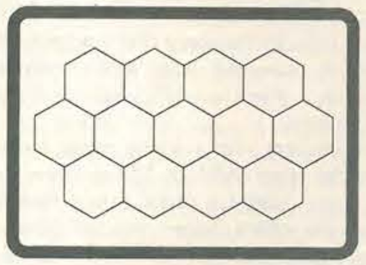


Fig. 5. Minolta's 14-segment honeycomb pattern metering - 13 plus background. Note that sensitivity is weighted to the subject. Spot metering is also possible by selecting just the centre segment, giving a reading of 2.7% of the image area (most SLRs offer this facility, and possibly centre weighting).

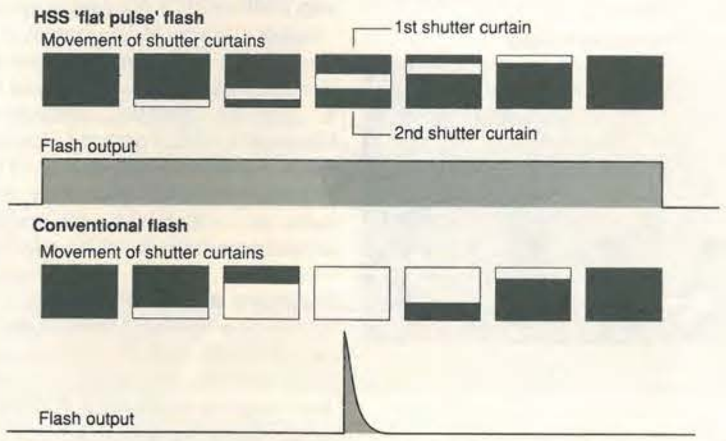


Fig. 6. High-Speed Sync (HSS). A conventional flash discharges the entire film in a single moment at once, just after the first shutter curtain opens completely. Minolta's Program Flash 5400HS's high speed sync (HSS) flash is a high frequency (50kHz) pulse that starts before the shutter opens and stops after the shutter closes. This 'flat' pulse resembles a constant light source, so HSS flash can synchronise with shutter speeds faster than the camera's x-sync. When the shutter speed exceeds the camera's x-sync the 5400HS switches from conventional flash to HSS flash. As it calculates the necessary amount of light with pre-lighting, you can shoot automatically in full exposure mode even with HSS flash lighting.

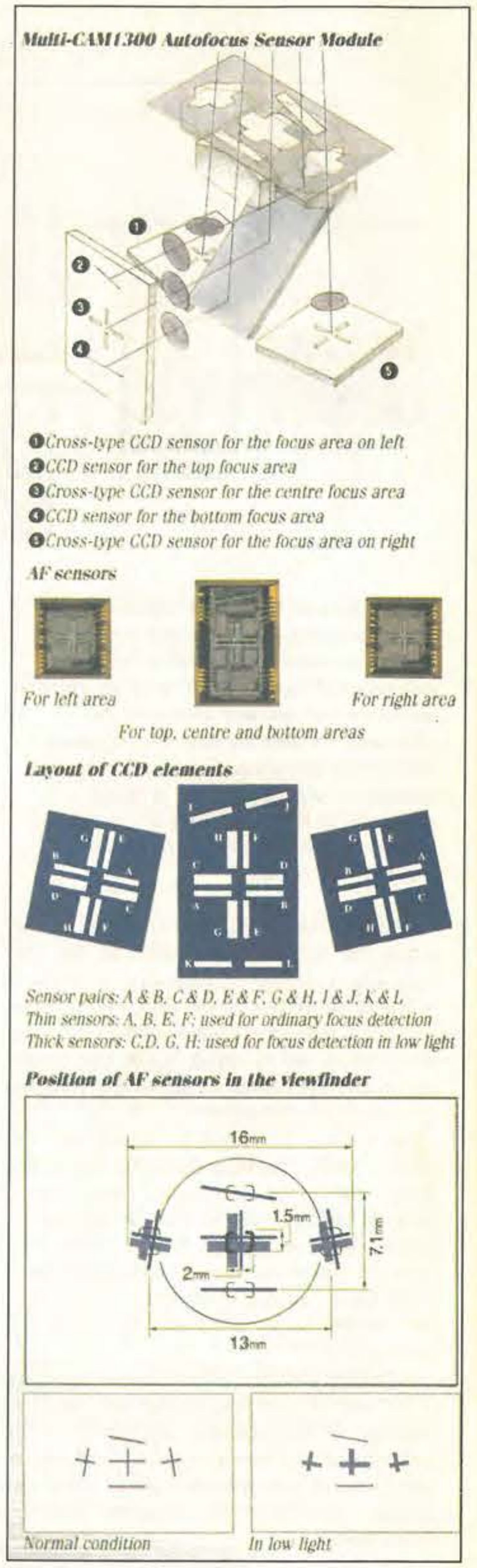


Fig. 7. Nikon F-5 autofocus sensor. Light is reflected down to the base to the mirror box, passes through a mask, and thence to the CCD line sensor pairs. Left, centre and right sensors are arranged in the form of a cross, those top and bottom into a line. The position of the sensors is indicated by brackets (an electrochromic device shows the focus area selected).

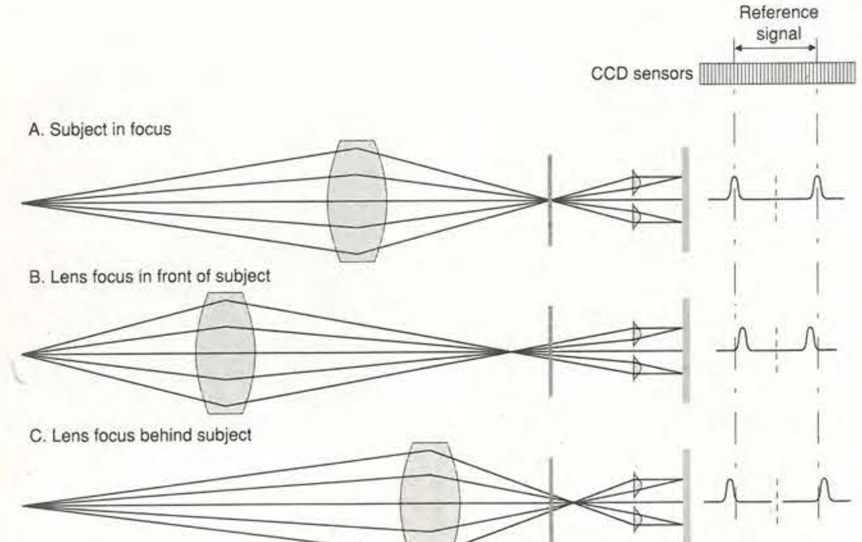


Fig. 8. Distance between the images on the ccd sensors varies depending on focus condition. When subject is in focus (A), distance is equal to a reference signal programmed into the automatic focus cpu. If distance is less (B), lens focus is behind subject. This is essentially a peak detection process.

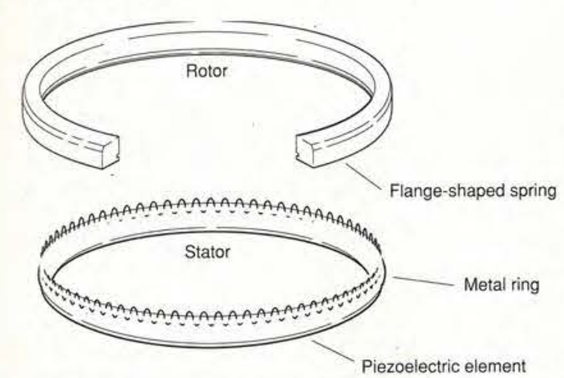


Fig. 9. Canon ring-type ultrasonic motor. The piezoelectric element in the stator generates rotational oscillatory waves to drive the rotor by functional force, it has high power output, high speed, and is virtually noiseless.

are read to analyse every detail; these variable sized groups are then used to calculate a signal representing average brightness plus contrast signals. These signals, together with that from the selected focus area, are then evaluated and compared by the cpu with algorithms in the camera's database made from more than 30,000 real scenes.

Next the signals are combined with distance information from the lens to determine exposure. Results from this processing determine whether the lens aperture is set in shutter priority mode or the shutter speed set in aperture priority mode, or both set in program mode.

The F5 is also the first camera to have 'flexible' centre weighted metering. Normally in this mode, 75% of the sensitivity is concentrated within a 12mm circle, but the size can be changed to 8, 15 or 20mm by custom settings in the camera. Alternatively, it can be fully customised by linking to a computer.

The computer link enables a full range of functions to be altered, in addition to the variety of settings available in the camera. It also enables remote control of the camera, downloading of shooting data, and so on. Some other makes of camera have internal customisation, and/or may offer slot-in customising rom and eprom cards.

Returning to exposure metering, without colour to consider other cameras make do with a silicon photo cell, **Fig. 4**. In the top Canon and Minolta models, for example, the photo cell is divided into 16 and 14 segments respectively, **Fig. 5**. The brightness detected by each segment is evaluated and compared with that of the other segments to give an overview of the lighting. The systems also weight the sensitivity to coincide with the selected focus area.

When using through-the-lens, or ttl, flash metering, these cameras additionally weight exposure to the focus area. This is done by a photo-cell sensor in the base of the mirror box from light reflected off the film, Fig. 4. When exposure is correct a quenching signal is sent to the electronic flash unit for a thyristor to terminate output.

New flash technology

A growing trend in flash technology is high speed sync, or HSS, developed first by Olympus. This overcomes the limitation imposed by the focal plane shutter on the maximum flash (or X) synchronisation speed, which is typically no more than 1/60-1/250 second.

The focal-plane shutter is a blind situated immediately before, and parallel to, the film. It consists of two curtains, each composed of lightweight blades. These blades are released sequentially by electromagnets. This electronically timed delay creates a moving opening whose width determines exposure time.

The X sync speed is the maximum at which the shutter is fully open for the flash to expose the film, **Fig. 6**. At faster speeds the second curtain begins to move before the first has reached the end of its travel so the flash would then expose just a strip on the film.

High speed sync flash units mimic the old slow-burning focal-plane flashbulbs by producing a series of very brief flashes covering the full duration of the shutter travel. This, in the case of Minolta's model, allows shutter speeds from X sync to as high as 1/8000 second, with others peaking at 1/2000 or 1/4000.

The advantages of this new flash system are bright, continuous, daylight-balanced lighting. Naturally, high-speed sync units can also be used with conventional flash.

Autofocus

The most controversial use of electronics in single-lens reflex cameras has been for autofocusing.

Firstly, electronics compromised lens performance due to the greater tolerances necessary for low resistance motorised focusing.

Secondly, the early focusing systems were crude and would just as likely end up out of focus as in. On top of this is a general resistance to change in the photographic world.

Now, lenses and automatic focus systems generally perform well and most photographers are content with them.

Nikon claims that its new system in the *F5* covers a wider area than any other, both horizontally and vertically. It achieves this by having five ccd sensor pairs consisting of approximately 1300 pixels, **Fig. 7**. Those for the centre, left and right of the frame are cross-type ones, while those for the top and bottom are a single line.

The cross-type sensors consist of both narrow and wide ccds, for normal and low light respectively. But if it is very dark then a special autofocus flash unit must be used with a led that projects a pattern of light onto the subject.

Automatic focus enhancement is now a built-in feature of most cameras. Incidentally, automatic focus systems need to predict where a moving subject will have reached between the time taken for the mirror to flip up and the shutter releasing.

All single-lens reflex cameras use a passive phase-detection system. Light rays coming from two widely separated areas of the lens pass through a partially transmissive area in the centre of the mirror to a sub-mirror behind it which reflects them down to the automatic focussing module in the base of the mirror box, Fig. 4. There, the rays are projected onto a pair of line image sensors where their separation is compared to a reference signal programmed into the automatic focus processor, **Fig. 8**.

TECHNOLOGY

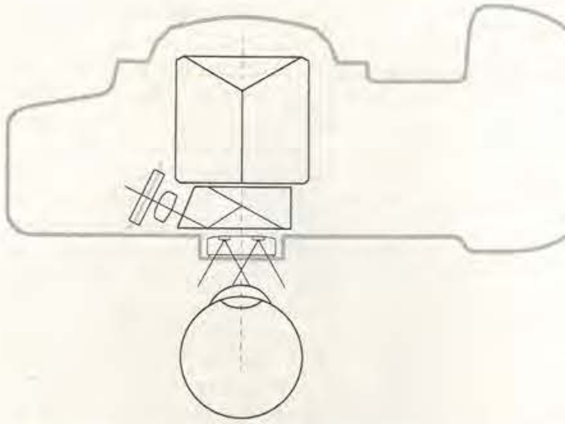


Fig. 10. The Canon Eye Select autofocusing technology has been borrowed from that in pilot's interactive helmets. Two IREDs at the bottom of the viewfinder surround project IR light onto the eye's surface which is reflected into the viewfinder and off to a CCO beside it to calculate at which focus area the eye is looking and activates it. Focus areas can also be selected automatically or manually.

If the projected rays are closer together then the lens is focused in front of the subject, if further apart then behind the subject. The automatic focus cpu processes the signal. It then communicates with the lens' cpu via electrical contacts in the lens mount to determine the type of lens and the amount of focusing movement required. In turn, the motor is driven to achieve focus.

The motor is normally in the lens but can also be in the camera body, coupled via a mechanical drive linkage. With in-lens drives, there is a trend towards ultrasonic motors, which are small and light, quiet and fast, and stop quickly and accurately. Canon was the first in this field, initially with a ring-type construction for stator and rotor, and now with several varieties of ultrasonic motor.

The principle is the same for all ultrasonic motors varieties: a piezoelectric element in the stator generates rotational oscillatory waves to drive the rotor by friction, **Fig. 9**. Nikon and Sigma have similar designs, but these go under different names since ultrasonic motor (USM) is registered by Canon.

Towards better accuracy

Modern automatic focus systems use more than one sensor pair for enhanced accuracy and detection speed, together with the convenience of focussing on off-centre subjects and tracking moving subjects by switching from one sensor to another. The sensor positions are indicated in the viewfinder.

The sensor pairs are generally of ccd type, but Canon uses its own *Basis*, an acronym forbase stored image sensor. This is essentially a mos device with a switched charge readout, but differs from that, and the ccd, by having an amplifier at the base of each pixel to improve the sensitivity and signal-to-noise ratio before 20× amplification by the on-chip gain circuit.

Autofocus controlled by the eye

Canon is also the only company to provide eye-select automatic focus on some of its single-lens reflex cameras – and video camcorders. This allows the photographer to select a focus areas by looking at it.

There are two infra-red leds in the viewfinder surround whose beams are reflected off the surface of the eye to a ccd sensor inside the viewfinder. From this sensor, the direction of vision is computed, **Fig. 10**.

Everyone's eyes are a different shape, and the size of the pupil in different lighting changes that shape. Some wear glasses and contact lenses. To accommodate these differences, users need to go through a calibration procedure. Despite all the variations, about 99% of users pass the calibration successfully.

Not all companies have gone over to autofocus lenses: Leica and Carl Zeiss have resisted because they believe that any optical compromise is too much. However, automatic focus is a fact of life.

Kyocera Yashica therefore developed an alternative method for the Contax AX – automatic back focusing – to provide autofocusing for manual Carl Zeiss lenses. This employs a movable inner chassis incorporating mirror box, pentaprism assembly, shutter and film plane, **Fig. 11**.

The chassis can move up to 10mm, driven by a direct drive ultrasonic motor along a matched ceramic collar and rail support under the command of the auto-focus controller. And it has the secondary advantage of allowing close (macro) focusing without the need for a 10mm extension tube.

And fully digital?

In little more than thirty years photography has progressed from a purely mechanical and chemical medium to one that is heavily reliant on electronics. The Nikon *F5*, for example, incorporates a network including three 16-bit, one 8-bit and one 4-bit processors. Other cameras are not far behind it. Even manual single-lens reflex cameras have electronic exposure and flash metering.

The next step, to purely electronic cameras, has already begun with a spate of digital models having been launched over the past few months. But their price-to-image-quality ratio is poor by comparison with film cameras. Therefore, conventional photography should continue for many years – with even greater use of electronics. ■

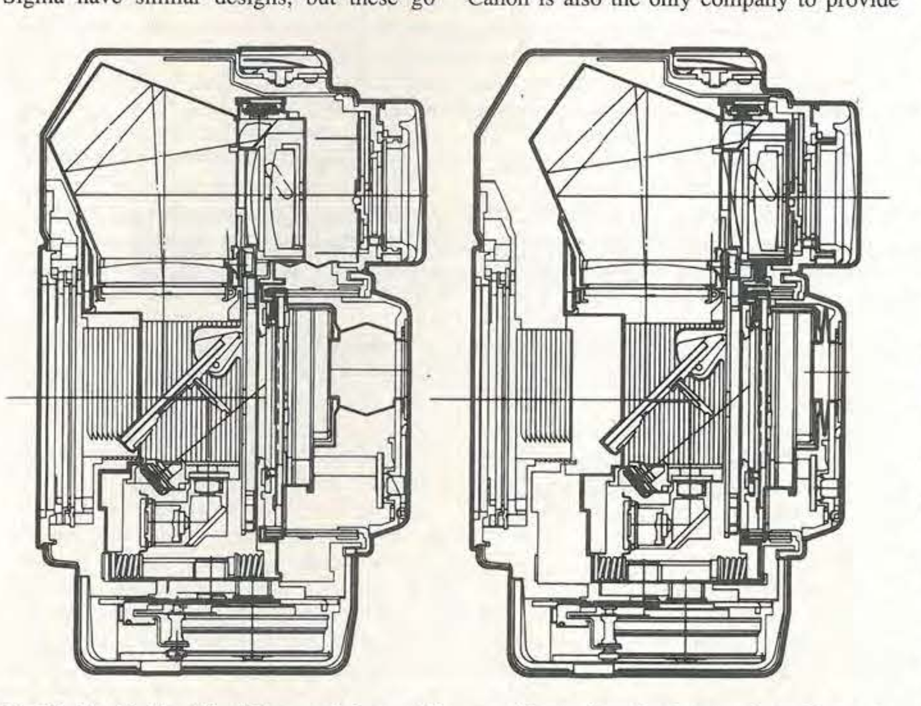


Fig. 11. The Contax AX achieves autofocus with manual lenses by using Automatic Back Focusing. This employs a moveable inner chassis to reposition the film plane over a range of 10mm – its position being indicated in the viewfinder by a bar display representing 2mm increments. Its maximum rear position allows close (macro) focusing with normal lenses.

Workbench EDA

With over 75k registered users worldwide, Electronics Workbench is the most popular circuit simulation package. Until now, Workbench has focussed on education, but how will the new EDA version be accepted by serious circuit designers? Rod Cooper investigates.

Many of you will be familiar with the previous version of *Electronics Workbench* as a low-cost simulator with a user-friendly graphical interface based on the virtual instruments concept. This traditional version has had a strong bias towards education and was relatively simple. But it was undoubtedly attractive to many designers. For those wanting a quick and easy check of basic circuit performance, *Electronics Workbench* had the virtue of getting away from net list entry and other abstract concepts used by other simulators.

The producer of *Workbench*, namely IIT, is now offering the same package but modified for professional use. It has more features, higher speed and a greatly expanded range of simulations. It also has a much larger component library.

This version recently made its appearance as *Electronics Workbench EDA*, called here *EDA* for short. It has no bias towards education, so there is no section devoted to fault injection. The original large selection of sample circuits has been reduced to just a handful, as an introduction.

For this review, I used a 120MHz Pentium with 16Mbyte of ram and both a 14in and a 20in monitor driven by a 1Mbyte Trident 9680 graphics card. Using both Windows 3.1 and 95, it ran well, screen redraws being acceptably quick. The speed of simulation under 3.1 was about the same as under 95. Typically, the analyses of the first screen in the monitors panel (**Fig. A**) ran in 2 to 3 seconds. There appeared to be no speed advantage using Windows 95.

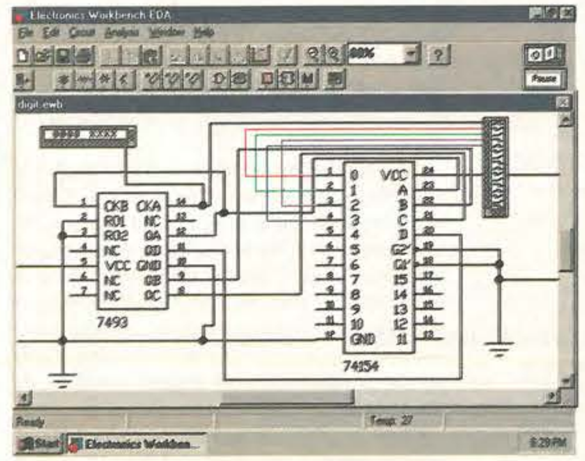
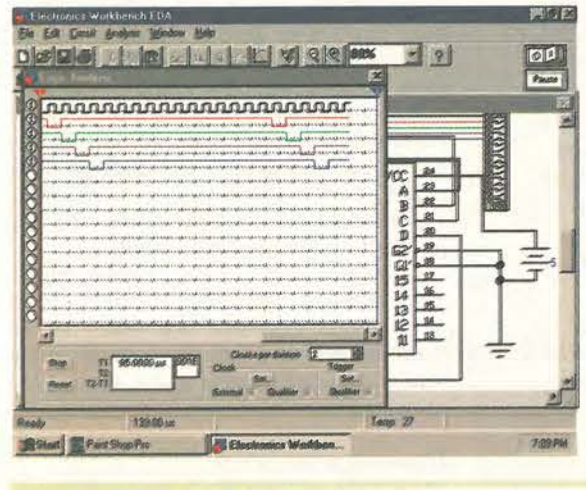


Fig. 1. Circuit of decoder/ripple counter used for checking out the logic analyser. Note the use of coloured wires to the analyser to improve circuit readability (640 by 480 pixel capture). Note that the drawing grid is off.



Logic analyser shown maximised. Note coloured traces correspond to wires in schematic, a good use of colour. The analyser does not show glitches, so there is no glitch control. The function labelled 'trigger' allows the analyser to start on receiving a preset word (640 by 480 pixel capture).

Operator's manuals and help

Four manuals are provided, plus a quick-reference card and installation guide. The user manual is derived from the previous version of *Electronics Workbench*, but with the references to the dos version removed. This makes it better reading. It consists of an introduction to using *EDA* and starts from basics, with plenty of explanation and a tutorial, so is a good introduction for a designer using a simulator for the first time. If you are used to simulators, you should fly through this book.

The second, larger book is a technical reference with explanations of the analyses and component models and is well-written and concise. It assumes to some extent that the reader is familiar with the basics such as Fourier, intermodulation distortion, simulation modelling, etc. For readers who are not, a reading list of a dozen or so publications is provided.

The third manual is a guide to importing and exporting net lists, and includes worked examples. There is no pressing need to look into the composition of net lists unless you absolutely have to, as *EDA* has schematic capture in many formats, but this is a good reference book if you want to know more.

Hardware and software requirements

This software needs Windows 3.1x, 95 or NT. There is no dos version. It comes on six floppies and installation is simple. Software protection is by personal identification and serial number.

The recommended minimum pc is a 486 or better. Under Windows, 8Mbyte of ram is required, under Windows NT, 12Mbyte. In all three cases, the recommendation 12Mbyte. You also need 20Mbyte of disk space. Since *EDA* is essentially a 32-bit program, the 32-bit driver WIN32s is installed automatically for Windows 3.1 users.

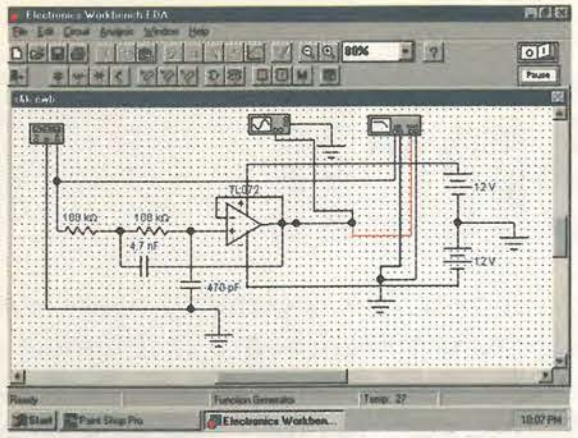


Fig. 2. Sallen & Key filter circuit used to produce the following two analyses (640 by 480 pixel capture). Here, the dot grid is turned on.

The fourth book is a small volume listing the ics and models in the package. These four books, taken together, constitute a comprehensive piece of documentation.

Mixed mode feelings

There is not much reference to mixed-mode simulation except for a brief reference as to how it is achieved. As it is a strong point of *Electronics Workbench*, which is promoted as "true" mixed-mode in the advertising, one would perhaps have expected more about it, but mixed-mode does not even appear in the index of the books.

Workbench's mixed mode is clearly regarded as sufficiently easy as not to require a chapter of its own, and this is in fact true. I tried mixed-mode simulation by adding an analogue buffer amplifier to **Fig. 1** and the simulation appeared seamless. Like previous versions of *Electronics Workbench, EDA* uses its own automatically inserted proprietary a-to-d and d-to-a interfaces on digital components to achieve mixed-mode simulations.

There is a fair amount of on-screen help to supplement the user manual. I found I needed to use this often at first, as the user manual is quite short. Also, there is a good system of prompts for when simulations go wrong, but these are rather terse. For example, you may receive a short message saying that the simulation aborted because a capacitor was disconnected, but it doesn't tell you which one. In a circuit of ten or twenty capacitors this is not very helpful – but is still better help than that provided in some competing simulators.

Reading through various computer magazines, technical support for software seems to be a hot potato these days, so I checked out the technical support at Coventry – no problem here, a quick and efficient advice and no telephone queues.

Drawing schematics

As you can see from **Fig. 2**, the screen format follows the standard Windows convention. Panning is done with the scroll-bars, and autopanning is performed when placing components.

Drawing is done on one very large 'virtual' page. Many users will prefer this to having a multi-page facility, but it is possible to generate sub-circuits and store them as icons. This is quite similar to having a multi-page function. There is no autosave – a feature which I would definitely like to see added. During the review there was a power cut and, yes, I was caught out.

Many of the present generation of simulators use schematic capture instead of net list entry. Some have been criticised because the drawing system has left a lot to be desired. Usually this has been on the grounds of it being awkward and therefore slow to pick, place and specify components. In this area, *Electronics Workbench* scores well.

Selecting and placing symbols is both intuitive and easy. As in version 4, symbols are taken from a number of parts bins pre-stocked with generic parts. There are 13 of these bins, each holding up to two dozen symbols each. One extra bin is provided that you can fill with your own preferred choice of symbols. These bins have been re-designed to take up much less screen space than the previous versions.

Out of the bin

A bin can be opened with a single mouse click. Opening a second bin automatically closes the first, but it is possible to open several at once to form a palette, as in graphics programs.

Symbols are placed using drag-and-drop and are easily erased – four mouse clicks – and replaced. Like many Windows programs, you are asked if you really want to erase the selected part; this adds an extra click and is annoying.

Specific information on each symbol is entered at a later stage, from the main library of model types. This system is highly suitable for simulation as experiments can be quickly set up and altered without going into detailed specification. This contrasts with the slower pcb-drafting type of schematic drawing systems using text components selected in advance from the library and dumped in a single parts bin.

Despite the very large library, searching for specific type information to attach to the generic symbols seemed very quick. By picking a particular schematic symbol you are automatically placed in the correct library volume for the symbol involved. You do not have to refer to a library index, as you do with some systems. It is clear that a lot of effort has been put into making manipulation rapid and intuitive and there are a lot of nice touches like this one throughout the program.

Wiring up

Still in pursuit of speed, symbols are connected up using an automatic wiring tool. For those not familiar with this facility, you click on a symbol's terminal, drag the mouse to another terminal and release. An orthogonal connection is then automatically drawn for you. This process is assisted by a snap-to function, so spot-on accuracy is not required, although a fair amount of manual skill is still needed. There is no adjustment of the snap-to.

The automatic wirer works well for small circuits. On large circuits it produces many corners and the routeing becomes devious. Like a pcb autorouter, the automatic wirer finds the going tough when there are many components, or if component spacing is close. In these conditions it does not do as well as a human. If you do not mind the circuit looking a bit untidy, then this does not matter; the simulations will still work – and it is very quick.

I found large, unedited schematics harder to read than those done by hand. The handbook suggests colouring wires using the six-colour option to clarify schematics, and I found this very useful in reducing this effect.

If you space the components out, the automatic wirer can give better results, but this takes up more screen space. As a result, you will be doing more panning than you should to see the circuit. Besides, screen space is always at a premium. But you may have to space the circuit out anyway, because text is non-manoevrable and you may need the extra space to avoid connections running through text.

If you have to present a good-looking schematic, for a report for example, then it will be necessary to tidy the circuit up by editing. This is done by a rubber-banding method, except that the connections stay orthogonal. I discovered that sometimes the auto-wirer fiercely resists attempts at editing, especially when previous editing has produced a few tight corners.

Occasionally, on large circuits, I have seen it run a wire axially through a resistor, giving some very strange effects. Also, until you become attuned to the system, it is possible to create an unintentional mess with rubber-banding.

In my view, this automatic wirer will be something the purchaser of *EDA* will hate or love. I would like to see *EDA* provided with an alternative manual schematic wiring program. If it were, everyone would be catered for.

Component libraries

To complement the wider range of simulations, the library of device models has expanded to 8000 types. This is a large library by any standard. I scanned it, looking for gaps but it it seemed very comprehensive.

For making up schematics, there are over 100 analogue components and double this number in digital components, and several hybrids. There is, however, only one schematic component for a terminal, and no library volume of connectors. This is commented on in the main article.

My eye was caught by the non-linear transformer modelling as this component is often not accurately modelled in simulators in this price bracket. If you want a bench-mark, then this is a good component to check out. The model is much improved over the previous version of *Workbench* – with 16 parameters compared to 5, it is clearly more useful.

Simulations and virtual instruments

EDA keeps the same range of virtual instruments as before, namely two-beam oscilloscope, bode plotter, autoranging multimeter, voltmeters and ammeters in any amount, function generator, logic analyser, logic converter, and word generator. Some of these have been improved, for example the logic ana lyser has been up-graded from 8 channels to 16.

There is no pulse generator or piecewise function in the virtual instrumentation. If you want these, you have to open the 'sources' bin. In this bin, there is an impressive number of extra functions such as an fm signal source, various voltage-controlled oscillators and piecewise and one-shot pulse generators. All of these are set up via a menu system.

In addition to virtual instruments, *EDA* has a number of analysis tools to supplement the simulations on the virtual instruments. These analyses are; dc operating point, ac frequency (phase and amplitude) transient, Fourier, intermodulation, noise, parameter sweep, temperature sweep, pole zero, ac and dc transfer function, ac and dc sensitivity, worst case, and Monte Carlo. There is one notable gap in the range of analyses provided – there is no analysis giving a plot of input impedance or output impedance against frequency.

The results from these analyses are presented either as a plot or in tabular form, and they run full-screen. On trying them, I found good continuity of style and technique, which should enable an operator to go from one to another without any mental gymnastics.

I found the features available in each analysis gave good coverage and scope, and they were particularly easy to use. For example, the ac analysis which provides plots of gain and phase covers the range 1Hz to 1GHz and allows several different scale types for the x and y axes. A typical scale choice provided for this and other plots is decade, decibel, log, linear.

Clearly, some of these analyses, like the one just mentioned, overlap with the virtual instruments. The choice is then yours; virtual instruments are easier to set up, analysis gives more detail and flexibility. This is especially true of the bode plotter, which cannot be expanded to fill the screen like the oscilloscope, and has no scaling on x or y axes. The bode plotter is obviously intended just for a snapshot of circuit performance.

Does monitor size matter?

On a 14in monitor the screen space available for drawing is 9 by 4.5in. This is not a lot, but is comparable with other Windows-based simulator programs. However, *EDA* performs much better with a larger monitor.

On the 14in monitor's 640 by 480 display, the grids on a few of the graphs showed slight merging together due to being too closely-spaced. This effect, which does not seriously impede reading of the graph, is shown in Fig. A. On the 20in 1024 by 768 display, all the simulation graphs appeared excellent as Figs. B, C and D show.

EDA now has a zoom feature. This is a very welcome addition. On a 14in monitor, and even on a 17in 1024 by 768 display, one used to have to squint at the symbols to make them out, but now with five levels from 50% to 200%, all is clear.

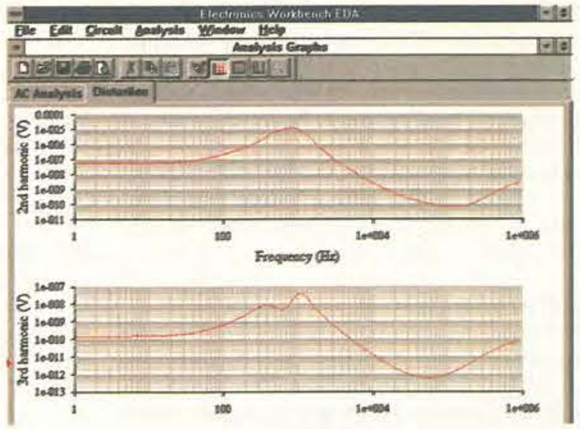


Fig. A. Intermodulation analysis of S & K filter. Note that on a 640 x 480 display you can expect some merging on graph lines as seen here but the graphs are still readable. At higher resolutions, clarity is excellent (640 by 480 pixel capture).

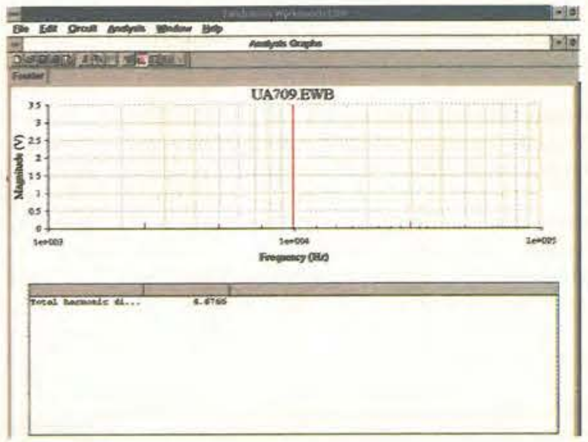


Fig. B. Typical Fourier analysis, for the 709 op-amp, which can also be presented as a line graph instead of a bargraph (1024 by 768 pixels).

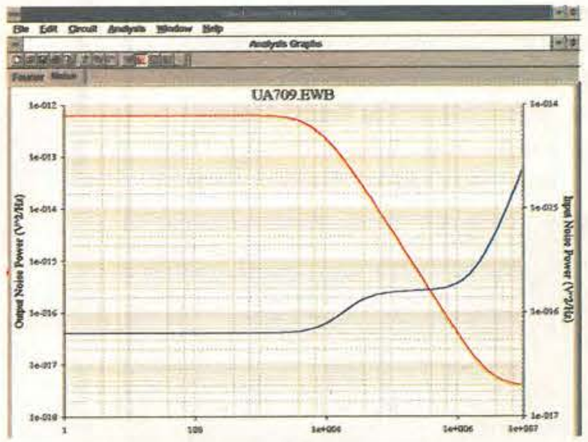


Fig. C. A plot of 709 op-amp noise (1024 by 768 pixels).

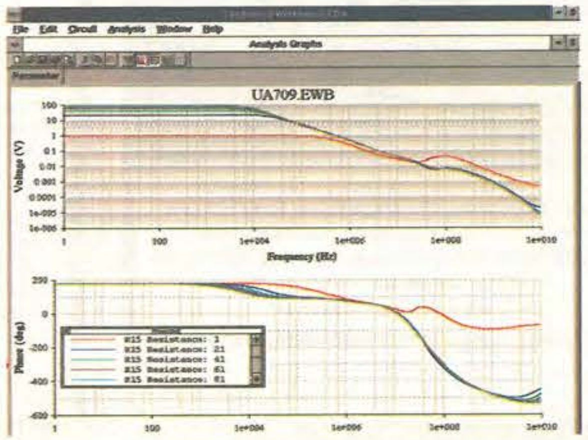


Fig. D. 709 op-amp parameter sweep, showing amplitude and phase at the output when just one resistor in the op-amp is changed from 1k to 100kΩ in 20kΩ steps. Note the clarity of the graphs compared to Fig. A (1024 by 768 pixels)

EDA uses Spice 3, whereas *Electronics Workbench* version 4 used Spice 2. All the simulations run much faster than *EDA*'s predecessor, version 4, which was acknowledged to be rather slow. The claimed figure is ten times faster.

The increased speed puts this package on par with most other simulators in this class. If you have previously used version 4, the speed increase is conspicuous.

This review is too short to detail every analysis, so I have shown several screens of simulations on a Sallen and Key filter, a 4-16 decoder/ripple-counter, and the circuit of the *709* op-amp. This will give a good idea of the style and scope of *Workbench EDA*.

Schematic capture and pcb layout

When using *EDA* just for simulations, there is normally no need to delve into net lists. However, if you need to export information to other systems, the package can produce net lists in several formats. These are Spice, Orcad, Protel, Tango, Eagle, and Ultimate. The most likely transfer would be to a third-party pcb-layout program, and if this is Windows-based. such a transfer is easy.

As I mentioned earlier, there is no library of connectors, such as D15, DIN41612, etc, for schematic drawing so these components cannot be transferred in the net list.

If you have a pcb-program with schematic capture, no problem. You simple add the connectors in the pcb-schematic after net list transfer, and re-process the net list. If this is not possible in your pcb drawing program, you could edit the net list or rat's nest in the pcb program in order to add the connectors before routing, but this slows down what should be a quick and easy operation and is most unwelcome.

Alternatively, you could draw the schematic in the pcb-producing program, then import a net list for simulation in *EDA*, but if the schematic has connectors already placed a whole raft of error messages appears. You are then obliged to edit the schematic in *EDA*. Again, for a designer in a hurry this is not welcome.

If the package is intended for commercial use, where the end product is likely to be a pcb design, it needs to produce a schematic complete with connectors ready for pcb routeing – like other simulator programs. The solution to this problem is simple; *EDA* should have a library volume of connectors.

In summary

In its *EDA* version, *Electronic Workbench* now has a sufficiently wide range of features to make it very attractive in many fields of activity as a general-purpose simulator. There are still a few areas where things could be improved, but this is true of most programs.

With a price tag of £795*, excluding vat, the package is outside the reach of education and amateurs. It is clearly intended for commercial designers, who will be attracted by the good value for money-*EDA* represents.

Compared with its nearest rivals, the cost/benefit ratio is excellent. On the practical side, you don't have to be a specialist in simulation to produce good results. Any engineer familiar with Windows and already working with bench instruments will be up and running with basic simulations almost immediately.

But one of *EDA*'s best features is that it combines in one package the ability to do 'snapshot' simulations and more sophisticated analysis. The extra depth is there if you want to access it.

For overall speed in achieving results, ease of use, and the intuitive interface, *Electronics Workbench EDA* scores highly. ■

* A special Educational version is available. The reduced-featured version, *Electronics Workbench* V5.0, sells at £199.

I/O port for PCs

Pei An's data acquisition and control system interfaces via a pc's RS232 port. Suitable for a variety of data acquisition applications, the interface has two analogue inputs together with seven digital inputs and seven digital outputs.

This pc peripheral is an RS232 serial port data acquisition/control system that could form the hardware core of virtual instrumentation. As the RS232 serial port is a universal feature of all types of computers, this system can be used with any pc.

The system has two analogue input channels with 12-bit conversion resolution and an input voltage range of 0 to 5V. There are seven digital input channels and seven digital outputs.

Power for the system is derived from either an external 8-15V dc power supply, or by a 9V battery. The complete system is capable of being housed in a small enclosure. Control software also exists, written in Visual Basic and Turbo Pascal for Windows.

In the first part of this article, details of the hardware and working principle of the system are given. The second part focuses on how to write a Visual Basic software driver and dynamic link libraries (DLLs) for the system.

An outline of the data acquisition/control system is shown in **Fig. 1**. **Figure 2** shows the complete circuit diagram. From the diagrams, you can see that the system consists of five blocks. These are an RS232-to-ttl converter unit, an a-to-d converter unit, a digital input unit, a digital output unit and a power supply.

Operation of each unit is controlled by the pc serially via the RS232 port. The serial i/o architecture greatly reduces the number of i/o lines required in the hardware design. The penalty is that the data transfer rate of the serial port is low relative to that of the parallel printer port.

Powering the design

Power supply to the system can be an external 8-15V power supply or a 9V PP3 battery. A *78L05* 100mA +5V regulator supplies *MAX3232CPE, UCN5810AF* and *CD4021*. A *ZAB4040* voltage reference generates the power supply and +5V reference voltage for the *TLC1288* a-to-d converter.

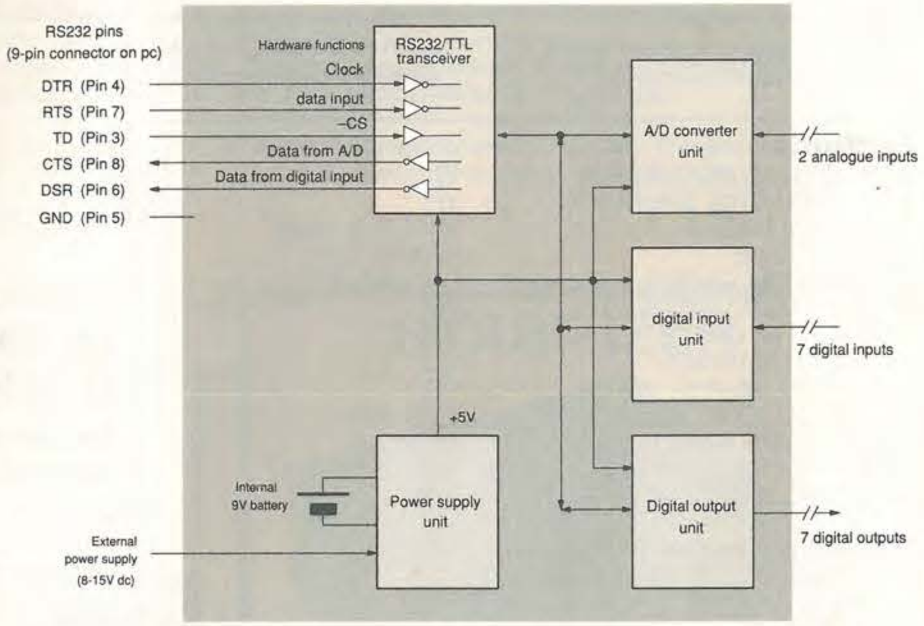


Fig. 1. The data logger/controller comprises five elements: RS232/ttl converter unit a-to-d converter unit, digital input and output units and power supply unit.

RS232 port

A detailed introduction to the operation and control of the RS232 port has been given in the article 'Computer RS232 wireless link' published in the June 1996 issue of *Electronics World*.

Briefly, an RS232 interface passes data in serial form via 25-pin D-type connectors. Since all 25 pins are rarely used, a modified version using 9-pin D connectors is now commonplace on pcs.

Figure 3 gives the pin layout and functions of the connectors viewed from the back of the computer.

In this design, the RS232 port is used unconventionally. The pins of the port are used to provide the following functions to the data logger/controller. Data control signals RTS and DTR are two output lines of the RS232 port. They are converted to ttl using ttl-to-RS232 transceivers and used to supply serial data and clock signal to the board, respectively.

RS232 control signals CTS and DSR are two input lines of the RS232 port and read the serial data from the a-to-d converter unit and from the digital input unit, respectively. The ttl voltage levels are converted to RS232 levels using an RS232-to-ttl transceiver.

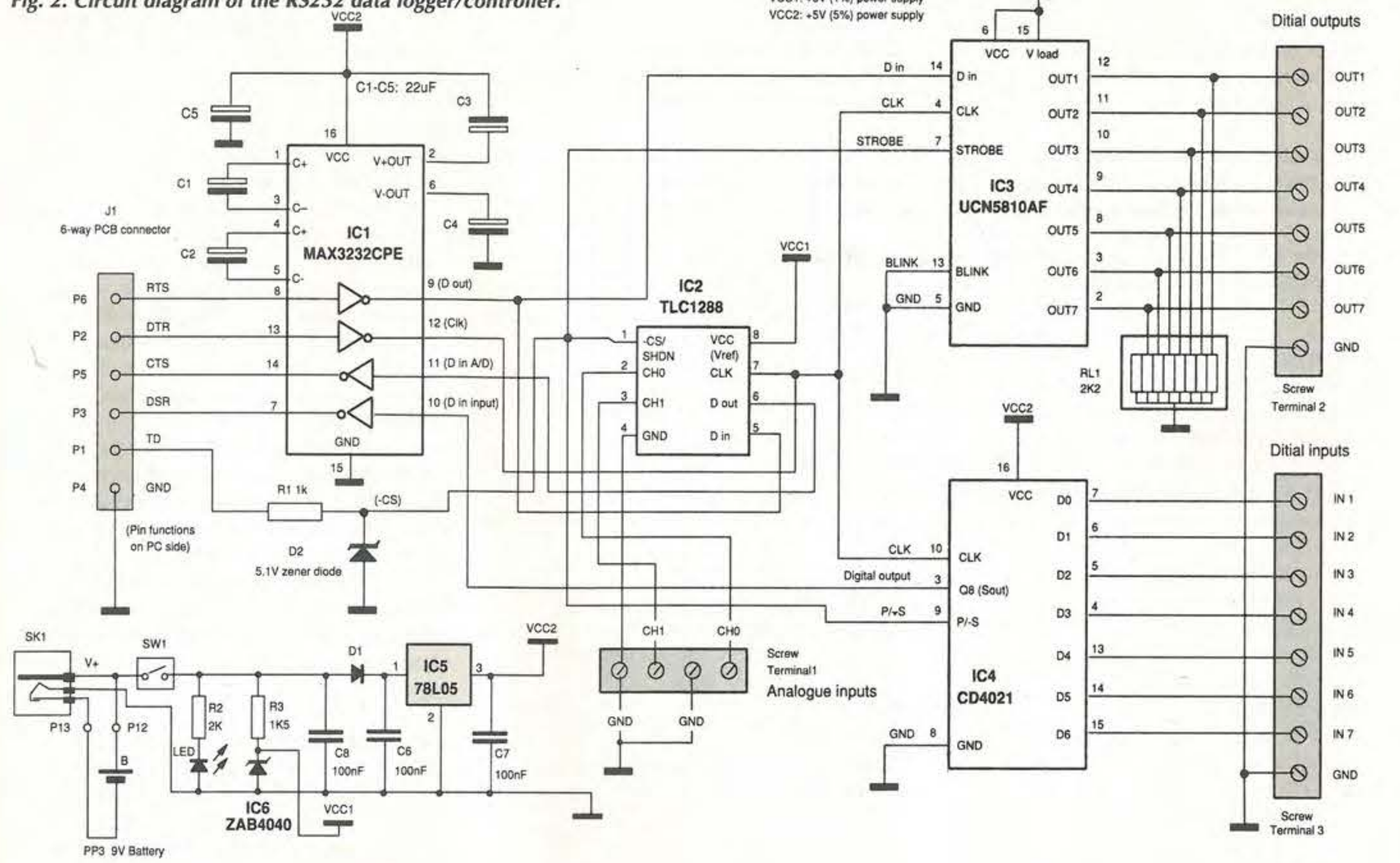
The transmit-data pin, of the RS232 port output, labelled TD, generates a control signal to the board. The voltage level of TD is converted to ttl using a voltage clamping circuit.

All ttl-to-RS232 transceivers have an inverting action. The voltage converter using the voltage clamping circuit does not cause inversion.

RS232-to-ttl conversion

The voltage level converter unit incorporates a *MAX3232CPE* low-power RS232-to-ttl converter chip.

Fig. 2. Circuit diagram of the RS232 data logger/controller.



This chip has similar electrical characteristics to that of the industrial standard *MAX232CPE* chip but it consumes much less current. It requires only a single-rail +5V power supply. Internally, this power supply is converted to +10V and –10V by a voltage doubler and a voltage inverter.

The *MAX3232CPE* converts RTS and DTR of the RS232 port, which are at RS232 voltage levels, into ttl. It also converts two lines from the data acquisition/control board, at ttl, into RS232 levels and feeds them to CTS and DSR, Fig. 3. All the converters cause signal inversion.

Another further RS232 output line, TD, is converted into –0.6V to +5.1V voltage level using a simple voltage clamping circuit consisting of a resistor and a zener diode. The voltage level is compatible with that required by the on board components.

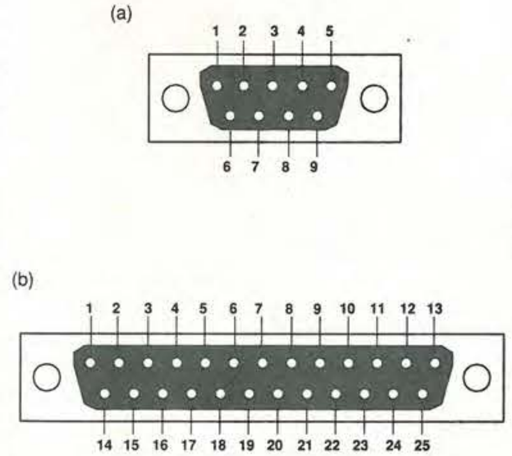
Digitising analogue signals

The analogue-to-digital converter is an *LTC1288* micropower successive approximation type, **Fig. 4**. It has 12-bit resolution and requires a 2.7V to 6V supply.

Pins 8 and 4 connect to the positive and negative rail of the power supply. Pin 8 also serves as the reference voltage input for the a-to-d converter. Therefore, the supply voltage must be precise, stable and free of noise and ripple.

Typical supply current of the chip is 260μA at a sampling rate 6.6kHz with a 2.7V rail. In standby mode, the supply current drops to several nanoamperes.

(a)



(c)

No of pins 25	9	Name	Direction (for pcs)	Description
1		Prot	–	Protective ground
2	3	TD	Output	Transmit data
3	2	RD	Input	Receive data
4	7	RTS	Output	Request to send
5	8	CTS	Input	Clear to send
6	6	DSR	Input	Data set ready
7	5	GND	–	Signal ground (common)
8	1	DCD	Input	Data carrier detedt
20	4	DTR	Output	Data terminal ready
22	9	RI	Input	Ring indicator
23		DSRD	I/O	Data signal rate detector

Fig. 3 Pin layout and functions of the RS232 connectors on pcs. (a) 9-pin male socket viewed from the back of the computer

The *LTC1288* has two analogue inputs, at pins 2 and 3, which can be configured into two input modes – single-ended and differential input mode. In single-ended mode, an input voltage can be applied to each input with respect to the ground. Two input channels can be used in this mode.

In differential mode, an input voltage is applied across the two inputs. Only one input channel is available in this mode. The analogue input leakage current is typically 1μA.

The *LTC1288* communicates with other circuitry through a four-wire serial interface. These four wires are –CS/SHDN, CLK, Din and Dout. Selection of the chip is carried out by taking –CS/SHDN, at pin 1, low. While the pin is high, the converter is in standby mode. This provides a means of controlling the *LTC1288* if a number of the ics are connected in a shared bus.

Clock input, CLK on pin 7, synchronises serial data transfer and determines conversion speed. At the falling edge of CLK, each bit of an a-to-d conversion result (12 bits) is sent out from Dout on pin 6. At the rising edge of the clock, an input bit appearing at Din is captured into the IC.

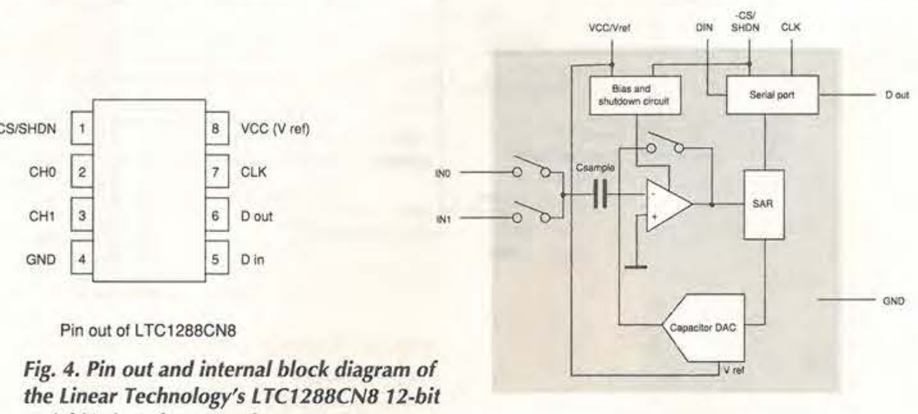
Figure 5 shoes how data transfer is initiated at the falling edge of the chip select –CS/SHDN. Next, the IC looks for a start bit. A start bit is a logic 1 appearing on Din and it is recognised by the *LTC1288* at the rising edge of the CLK input.

Next, a three-bit input word comprising bits 1, 2 and 3, shifts into the IC from the Din input at the following three rising edges of the CLK input. These three bits configure the input mode and the serial data output format.

Table 1. Functions of the interface's control word. Bits 1 and 2 determine the input mode while bit 3 selects the format of the data from the a-to-d converter.

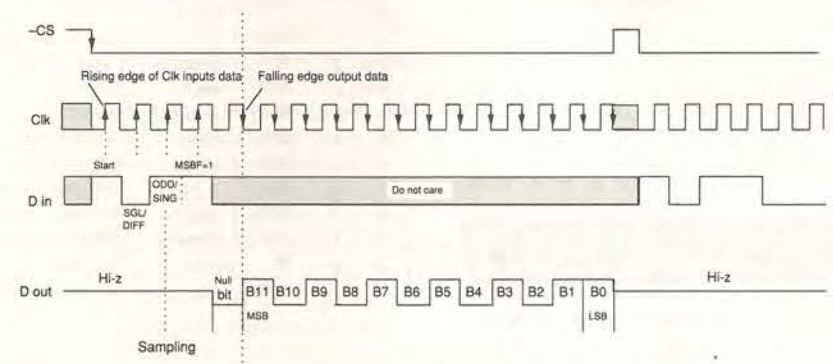
Bit 1	Bit 2	Channel	Channel	GND
SGL/–DIFF	ODD/SIGN	0	1	
1	0	Vin+		Vin–
1	1		Vin+	Vin–
0	0	Vin+	Vin–	
0	1	Vin–	Vin+	

Bit 3	Function
1	A-to-d conversion bits shift out msb first (B11 to B0)
0	A-to-d conversion bits shift out lsb first (B0 to B11)



Pin out of LTC1288CN8

Fig. 4. Pin out and internal block diagram of the Linear Technology's LTC1288CN8 12-bit serial i/o interface a-to-d converter.



SGL/DIFF=0, differential input, ODD/SIGN=1: IN1 selected, MSBF=1: MSB first

Fig. 5. Timing sequence of the LTC1288 a-to-d converter. After –CS falls the LTC1288 looks for a start bit. After the start bit is received, a 3-bit input word is shifted into the D_{in} input which configures the IC and starts the a-to-d conversion. After one null bit, the result of the conversion is output from the D_{out} line.

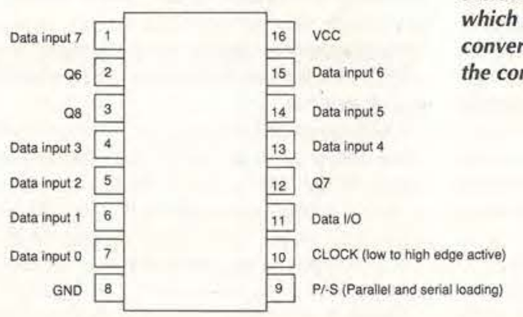


Fig. 6. Pin out of the parallel-to-serial converter circuit using CD4021.

At the falling edge of the fourth clock, an a-to-d conversion starts. Immediately after this falling edge, a null bit (logic 0) appears on Dout.

At the next 12 falling edge of the clock input, the 12 bits of the a-to-d conversion result appear on Dout. During this time the bits appearing on Din do not have any effects on the converter. Because of this, data bits can be used for driving other units.

Bits 1 and 2 of the three-bit input word configure the analogue inputs. For a selected mode, the converter will measure the voltage between the two channels indicated by Vin+ and Vin–. Bit 3 selects the output data format either as most or least significant bit first, **Table 1**.

Transmit data line TD is connected to –CS/SHDN via a non-inverting voltage translator. This line is normally low. A low-to-high-then-low pulse applied to the TD line initiates an a-to-d conversion.

After passing through the *MAX3232* and being inverted, DTR is connected to CLK. Similarly, RTS is connected to Din. Before being fed into CTS, Dout (pin 6) is inverted by the *3232*.

Digital input

Due to the fact that a RS232 interface only provides a very limited number of input lines, special circuitry is needed in order to read a large number of inputs.

The circuit in this design is a *CD4021* parallel-in/serial-out shift register, **Fig. 6**. The IC has a clock input, a parallel-in/serial-out control input called P/–S, a serial data line, eight parallel data inputs and three parallel data outputs.

Firstly, eight bits of data are present at the eight inputs, D_{0-7}. When P/–S is set logic high, the 8-bit parallel input data is loaded into the *CD4021* regardless of the status of the clock. Next, P/–S is brought low which terminates the parallel-in operation and starts the serial-out operation.

At the low-to-high transition of the clock input, data bits D_{7-0} are shift out from pin Q_7. After eight clock cycles, the eight-bit parallel data present at the inputs is serially transmitted from Q_7.

In this circuit, the non-inverted TD line connects to P/–S, and is normally at logic low. When a low-to-high-then-low pulse is applied to the line, parallel data is latched into the internal register and the *CD4021* enters the serial output mode.

The parallel external input data DB_{6-0} are fed into the *CD4021* from D_{6-0} of the *4021*. Serial data output from the *CD4021*, Q_8, connected to DSR of the RS232 port via the *MAX3232CPE*.

Digital output

The digital output unit uses a *UCN5810A* ten-bit serial-input latched driver, **Fig. 7**. The maximum voltage to the logic circuit is 15V. Quiescent current when all outputs are off or on is typically 200μA.

The device has ten bipolar npn open-collector drivers. Each is capable of sourcing 15mA

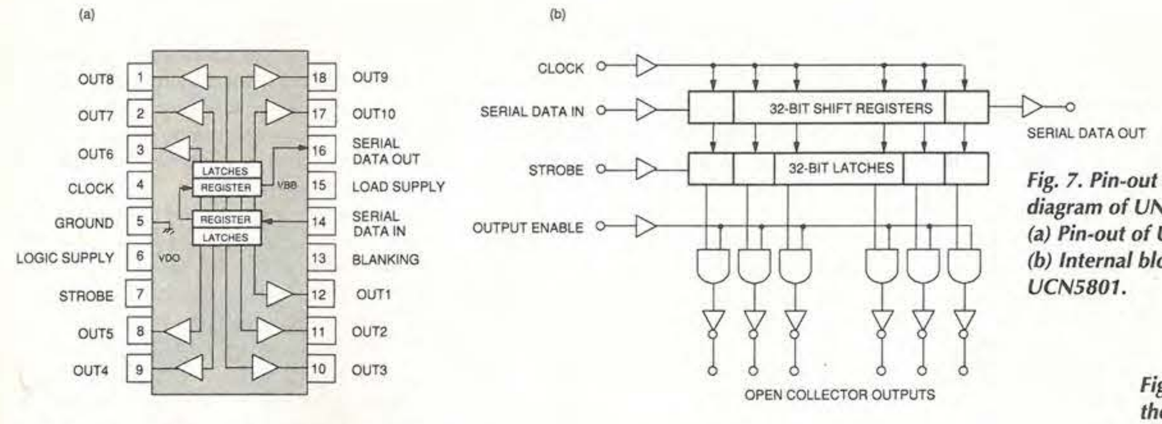


Fig. 7. Pin-out and internal block diagram of UNC5801AF
(a) Pin-out of UCN5801
(b) Internal block diagram of the UCN5801.

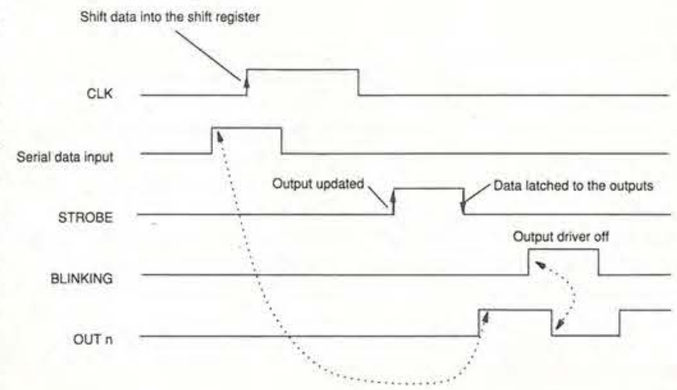


Fig. 8. Timing sequence of the UCN5810. Serial data present at the input is transferred to the shift register at the low to high transition of the CLOCK input. On successive clock pulses, the registers shift data towards the serial data out. Information present at any register is transferred to the latch when the STROBE is high. When BLINKING input is high, the output drivers are all turned off. If it is low, the outputs are controlled by the state of latches.

and sinking 40mA with a maximum control voltage of 60V. It also has one c-mos data latch for each driver, a high speed ten-bit c-mos shift register and c-mos control circuitry.

Control of the device is achieved through four c-mos compatible lines, which can be directly connected to c-mos output lines. If they are connected to ttl output lines, pull-up resistors should be used.

Referring to **Fig. 8**, serial data present at the input is shifted into the shift register on the low-to-high transition of the clock. On the next clock pulses, the registers shift data towards the serial data output, Dsout.

Information presented at any register can be transferred to its respective latch when the strobe is high. The latch continues to accept new data as long as the strobe is high.

At the high-to-low transition of the strobe, data is latched. When the output enable input is low, all of the output buffers are switched off without affecting the information stored in the latches or shift register. When this input is high, the outputs are controlled by the state of the output of the latches.

Figure 3 shows how the device is used in the present circuit. Uninverted transmit-data line TD forms the strobe signal. It is normally low, which maintains the status of the parallel outputs previously latched.

When TD goes high, data in the shift registers are clocked into the output registers. After passing through the *MAX3232* and being inverted, DTR becomes the clock signal. Similarly, RTS is connected to the Din to supply the input serial data. The data input rate for this section could be as high as 3.3MHz.

Each used digital output is pulled up by a 2.2kΩ resistor.

Timing details

Timing of the circuit is shown in **Fig. 9**. A complete cycle starts when TD goes high from its normally low state. When it transmits data byte 0, the lines goes high and stays at high for a short period of time.

At the rising edge of TD, two actions take place. One is that data in the internal shift registers of the *UCN5810AF* are updated to the output latches and appears at the outputs OUT_{1-8}. Note that the data in the shift regis-

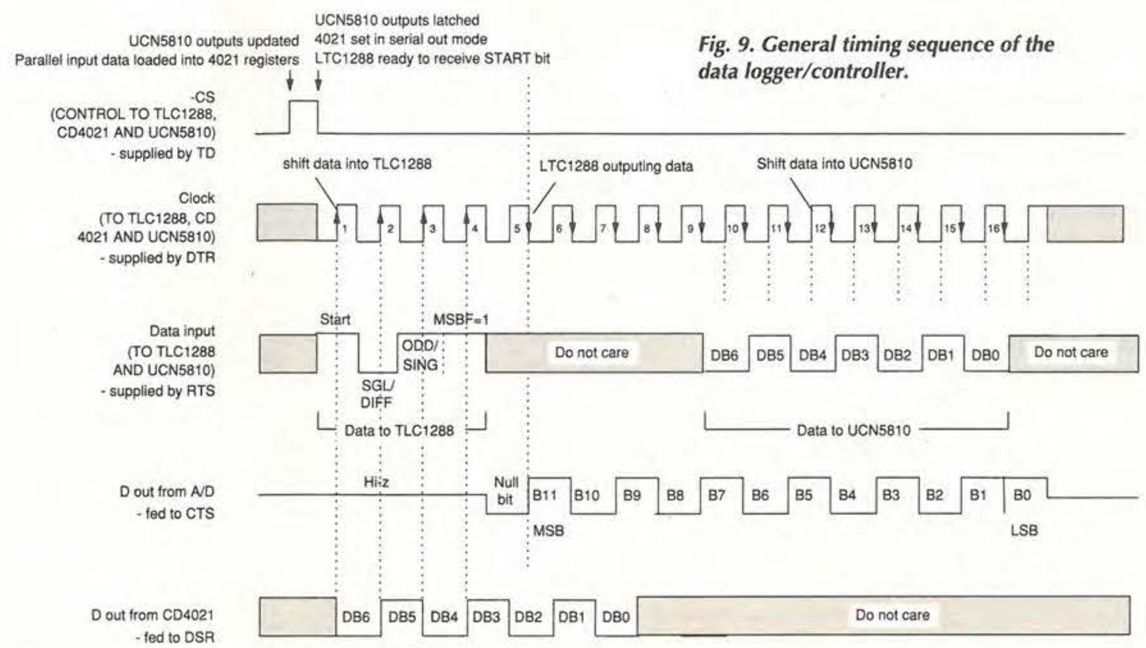


Fig. 9. General timing sequence of the data logger/controller.

ters were loaded in the previous cycle.

The second action is that the input parallel data to the *4021* is loaded into the internal shift registers. The eighth bit of the input data appears automatically on Q_8.

On going low, TD latches data in the *UCN5810AF* and sets the *CD4021* in serial-out mode. This low-going transition also initialises a conversion cycle of the a-to-d converter. Next, 16 positive-going clock pulses are applied to the *UCN5810* a-to-d converter, and *CD4021* through the DTR line.

The first four pulses shift in a four-bit control word to start the converter, configure the analogue input mode and select serial data output mode. At the low-to-high transition of each clock pulse, parallel data presented to the inputs of the *CD4021* is shifted out serially at the output, Q_8. This is read into the pc via the RS232 DSR line.

After four clock pulses, lines $DB_{6\text{-}3}$ of the input data are read into the computer. These clock pulses also shift data bits into the shift registers of the *UCN5810*, but these bits are not latched to the output latches.

There are 12 more clock pulses following. At each falling edge of these 12 clock pulses, each bit of the analogue-to-digital conversion result is shift out from D_{out} pin of the *LTC1288* and is read into the computer via the CTS line of the RS232 interface.

At the rising edge of the first three clock pulses, the $DB_{2\text{-}0}$ of the input data are shift out and read into the pc via the RS232 DSR line. At that stage, all the bits of the digital input data are read into the pc. These bits is combined into a single byte.

During the period of these 12 clock pulses, the data presented at the D input of the *TLC1288* do not have any effect on the converter. They are used instead to shift the data into the *UCN5810*.

Because only seven outputs are used for the *UCN5810*, only the last seven clock pulses are used to shift the data in. Serial bits are shift in at the low-to-high transition of the clock pulses with the most-significant bit arriving first.

Shifted data bits stay in the shift registers and are latched to the output latches at the next read/write cycle when the strobe line goes from low to high.

Figure 10 shows my prototype and demonstrates how compact the design can be.

Using the system

This data acquisition and control system can be used in various interfacing applications. By attaching suitable sensor circuits, temperature, pressure, humidity, magnetic field intensity, etc. can be read into the computer via the analogue inputs.

Some sensors already have a digital output format. In this case, the sensor can be connected directly to the digital inputs. The output can control various devices such as stepper motors and heaters etc. Obviously, additional power driver circuits will be needed for such purposes.

Although versatile, this data logger/controller system is not much use in applications where speed is important. I connected it to a P90 computer and I found that the rate of a-to-d conversion and digital input output is around 3.5kHz.

Software I have developed provides useful features such as automatic data logging, saving data onto disk, plotting data on the screen and controlling the data outputs. Windows software for controlling will be outlined in a future issue. For more information, see the Technical support panel on the next page. ■

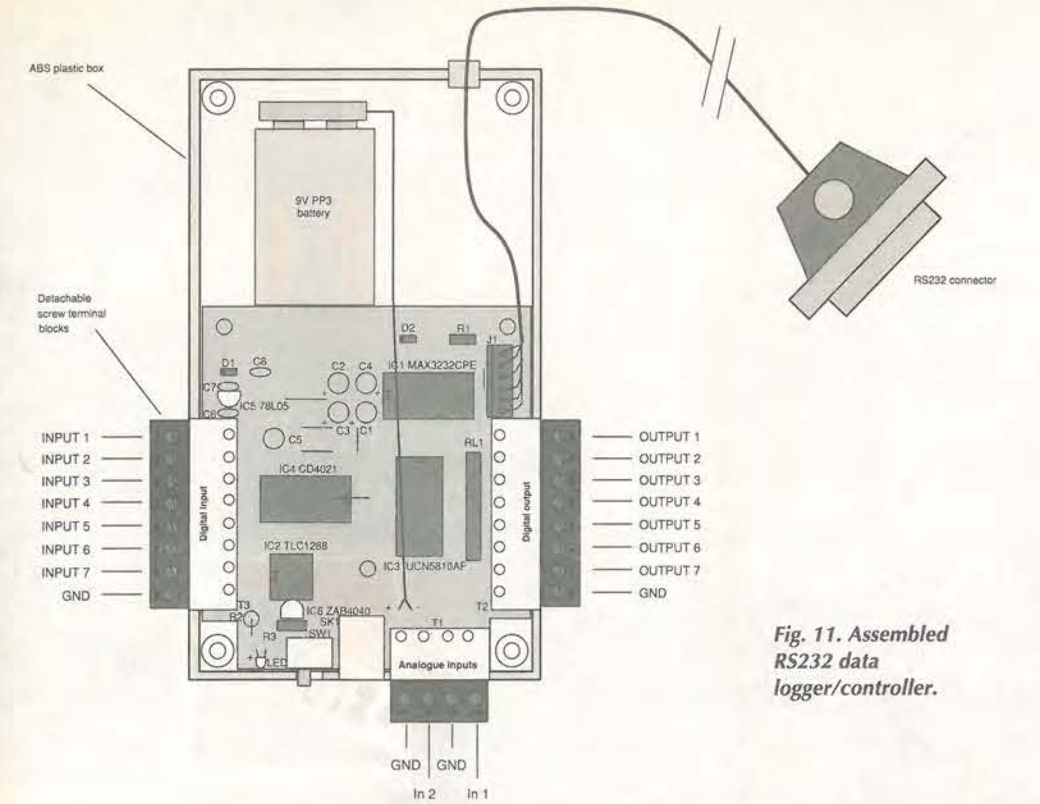


Fig. 11. Assembled RS232 data logger/controller.

Technical support

The i/o system described here is available in kit and in assembled forms from the author together with the Visual Basic source code, DLLs and executable files. Please direct your enquiry to Dr Pei An, 11 Sandpiper Driver, Stockport, Manchester SK3 8UL, U.K. Tel/Fax: +44-(0)161-477-9583.

Turbo Pascal for controlling data logger

The Turbo Pascal 6 program listed here has four basic functions, namely RS232(), Configure_RS232(), AD_converter() and Inputdata(). They control all the operations of the RS232 data logger/controller and can be called in user's Turbo Pascal 6 programs. Source code and the EXE file are available on floppy disks from the author.

RS232(x:integer):integer: Variable x can be 0, 1, 2, 3 or 4. This function is concerned with the port address of the COM ports installed on your computer. RS232(0) returns the number of installed RS232 ports. RS232(1) returns the port address of COMl; RS232(1) returns the port address of COM2, etc.

Configure_RS232(RS232_address:integer):integer;
RS232_address needs to be supplied to this function. It configures the RS232 port specified by RS232_address to a mode required by the RS232 data logger/controller.

AD_converter(RS232_address, Mode, Output_byte, Other:integer):integer
This code reads data from the a-to-d converter and latches Output_byte to the seven outputs. The function returns the a-to-d conversion result in integer. Value RS232_address should be supplied. Mode is 1, 2, 3 or 4 to select the input mode of the A-to-D converter. Output_byte is an integer between 0 and 127 while Other is used for future expansions.

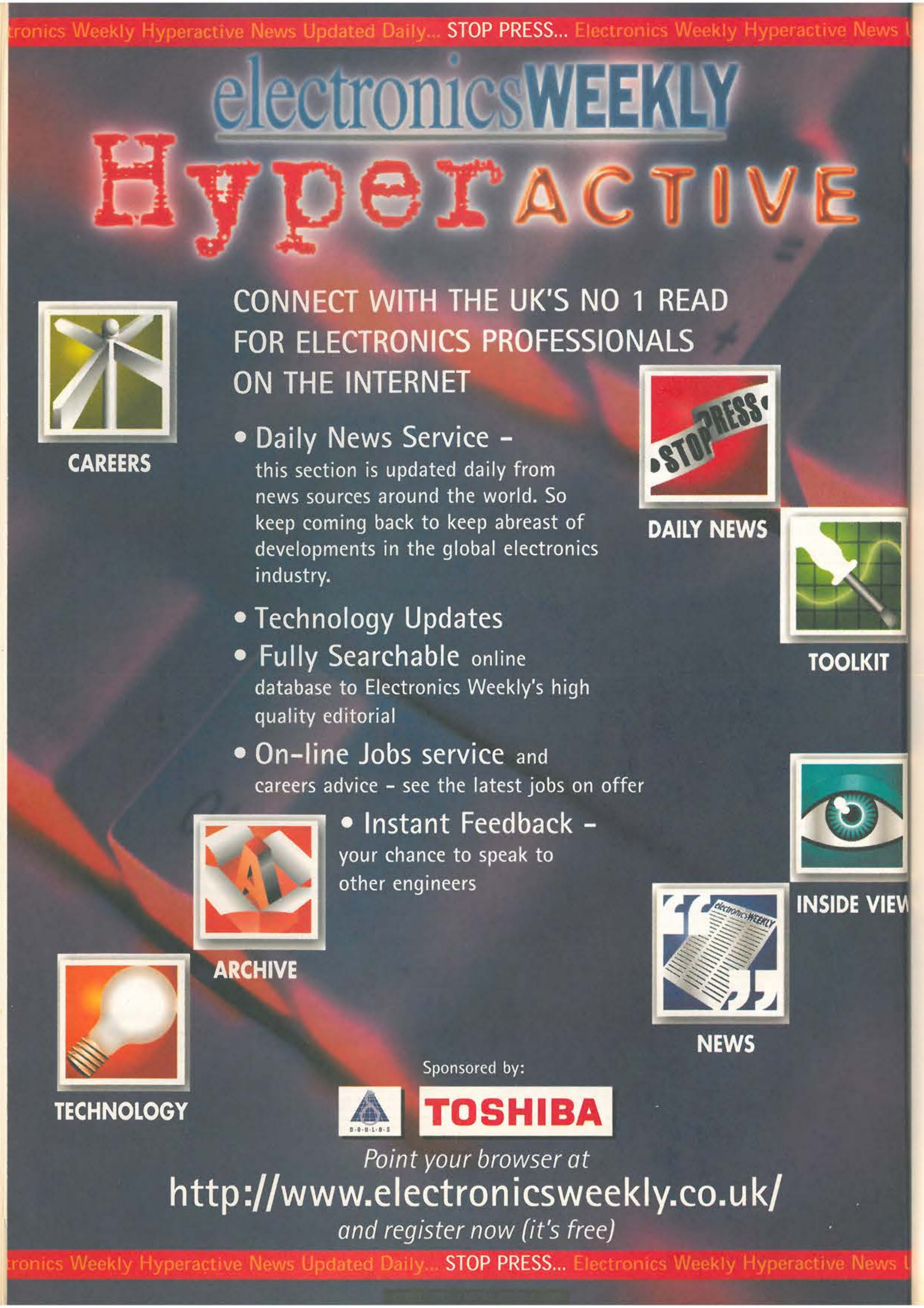
Inputdata(RS232_address:integer):integer
This function reads the seven inputs into the computer. RS232_address should be supplied.

Data logger program list, RS.PAS

```
{Copyright Dr Pei An, 2/5/97:
DTR (bit 0 of 04 offset register of UART, modem control): Clock
  signal, inverted in the circuit by RS3232
RTS (bit 1 of 04 offset register of UART, modem control): Data out
  signal, inverted in the circuit by RS3232
TD (00 offset register of UART, data register): -CS signal, not
  inverted (normally low)
CTS (bit 4 of 06 offset register of UART, modem status): serial
  A/D data input, inverted in the pc
DSR (bit 5 of 06 offset register of UART, modem status): serial
  digital data input inverted in the pc GND (ground)}

uses
    dos, crt;
var
dummy,COM_number,RS232_address,out_byte:integer;
Function RS232(x:integer):integer;
{Universal auto detect COM base address
          $0000:$0400 holds the printer base address for COM1
          $0000:$0402 holds the printer base address for COM2
          $0000:$0404 holds the printer base address for COM3
          $0000:$0406 holds the printer base address for COM4
          $0000:$0411 number of parallel interfaces in binary
format}
var
          number_of_COM, COM1, COM2, COM3, COM4 :integer;
begin
      number_of_COM:=mem[$40:$11]; {read number of parallel ports}
      number_of_COM:=(number_of_COM and (8+4+2)) shr 1;
      COM1:=0; COM2:=0; COM3:=0; COM4:=0;
      COM1:=memw[$40:$00];         {Memory read procedure}
      COM2:=memw[$40:$02];
      COM3:=memw[$40:$04];
      COM4:=memw[$40:$06];
      case x of
        0:           RS232:=number_of_COM;
        1:           RS232:=COM1;
        2:           RS232:=COM2;
        3:           RS232:=COM3;
        4:           RS232:=COM4
       end;
end;
Function Configure_RS232(RS232_address:integer):integer;
{Configure RS232 serial data format, Baud rate: 115200, Data
length: 5, Stop bit: 1, no Parity check. To achieve 115200 Baud
rate, a frequency divsor must be loaded into the UART}
var
          ij:integer;
begin
          port[RS232_address]:=0;
          for ij:=1 to 10000 do ij:=ij;
          port[RS232_address+3]:=
          128;{Loading serial data format, first bit of the
register is 1}
        port[RS232_address+0]:=1;  {LSB of the divsor is 1}
        port[RS232_address+1]:=0;  {MSB of the divsor is 0}
        port[RS232_address+3]:=0;  {Load divsor}
        Port[RS232_address+1]:=2;{2=Generate interrupt when TD
buffer is empty}
        delay(100);
end;
Function AD_converter(RS232_address, mode, outputdata,
Others:integer):integer;
{RS232_address, Base address of the selected RS232 port}
{mode: select analogue multiplexier mode
Mode 1, Single mode, Channel 0
Mode 2, Single mode, Channel 1
Mode 3, Differential mode, Channel 0 positive, Channel 1 nagative
Mode 4, Differential mode, Channel 1 positive, Channel 0 nagative
outputdata: digital output word (DB0 to DB6 bit, 7 bit in total)}
{others: for further expansion}
var
   ii, Single_differential, Odd_sign, dummy_byte:byte;
   IO_data: array[1..12] of byte;
   data:array[1..12] of integer;
   Digital_data:array[1..12] of byte;
   binary_weight, dummy:integer;

Procedure delay;
{A short delay}
var
          ij:integer;
begin
          for ij:=1 to 6 do ij:=ij;
end;
Procedure AD_control(datax:byte);
{procedures for controlling A/D converter, serial-in latch and
paralle-serial shift register}
var
          ij:integer;
begin
          port[RS232_address+4]:=1+2*datax; {CLK=0, Dout=datax,
start bit=1}
          port[RS232_address+4]:=0+2*datax; {CLK=1, Dout=datax,
start bit is clocked into the A/D converter}
        delay;
        port[RS232_address+4]:=1+2*datax; {CLK=0, Dout=datax}
        delay;
end;
Procedure Configure_mode;
{Assign values for Odd_sign, Single_differential}
{Mode 1, Single mode, Channel 0
 Mode 2, Single mode, Channel 1
 Mode 3, Differential mode, Channel 0 positive, Channel 1 nagative
 mode 4, Differential mode, Channel 1 positive, Channel 0
nagative}
begin
          case mode of
          1:  begin Odd_sign:=1; Single_differential:=0; end;
          2:  begin Odd_sign:=0; Single_differential:=0; end;
          3:  begin Odd_sign:=1; Single_differential:=1; end;
          4:  begin Odd_sign:=0; Single_differential:=1; end;
        else  begin Odd_sign:=1; Single_differential:=0; end;
        end;
end;
Procedure configure_output;
{Assign IO_data[ii] according to OUTPUTDATA, ii=1 to 12,
OUTPUTDATA should be 0-127}
var
          ij:integer;
begin
          for ij:=1 to 4 do IO_data[ij]:=0;
        IO_data[5]:=1-Outputdata and 64 shr 6;
        IO_data[6]:=1-Outputdata and 32 shr 5;
        IO_data[7]:=1-Outputdata and 16 shr 4;
        IO_data[8]:=1-Outputdata and 8 shr 3;
        IO_data[9]:=1-Outputdata and 4 shr 2;
        IO_data[10]:=1-Outputdata and 2 shr 1;
        IO_data[11]:=1-Outputdata and 1;
end;
begin
   configure_mode;
   configure_output;
   Binary_weight:=4096;
   port[RS232_address]:=0;
   {TD sends data. -CS goes low to high briefly then back to low}
   repeat delay until port[RS232_address+2] and 1 =0;
   for ii:=1 to 120 do delay;
   AD_control(0);                    {Start}
   Digital_data[7]:=(1-(Port[RS232_address+6] and 32)  shr 5);
   AD_control(Single_differential);     {}
   Digital_data[6]:=(1-(Port[RS232_address+6] and 32)  shr 5);
   AD_control(Odd_sign);
   Digital_data[5]:=(1-(Port[RS232_address+6] and 32)  shr 5);
   AD_control(0);
   Digital_data[4]:=(1-(Port[RS232_address+6] and 32)  shr 5);
   for ii:=1 to 12 do
   begin
       Binary_weight:=binary_weight div 2;
       Port[RS232_address+4]:=0+2*IO_data[ii]; {CLK=1,
Dout=Datax[ii]}
       delay;
       Port[RS232_address+4]:=1+2*IO_data[ii]; {CLK=0,
Dout=Datax[ii]}
       delay;
       dummy_byte:=(Port[RS232_address+6]);
       data[ii]:=(1- (dummy_byte and 16)  shr 4) * Binary_weight;
       if ii<4 then  Digital_data[4-ii]:=(1-(dummy_byte and 32)
shr 5);
   end;
   dummy:=0;
   for ii:=1 to 12 do dummy:=dummy+data[ii];
   AD_converter:=dummy;
   Dummy:=0;
   Binary_weight:=1;
   for ii:=1 to 7 do
      begin
          dummy:=dummy+digital_data[ii]*binary_weight;
          Binary_weight:=binary_weight*2;
      end;
   Port[RS232_address+7]:=dummy; {input digital data is
stored in the scratch-pad register
                             offset 07 of the UART}
end;
Function Inputdata(RS232_address:integer): integer;
{Read digital input data (7-bit) from the scratch-pad register,
offset 07 of the UART}
var
        ij:integer;
begin
        for ij:=1 to 10 do ij:=ij;
        Inputdata:=port[RS232_address+7];
end;
{ Main program }
begin
     clrscr;
     writeln('TP6 software driver for the RS232 data
logger/controller');
     writeln('Number of COM port installed:',RS232(0));
     write('Select the COM port (input 1,2,3 or 4): ');
readln(COM_number);
     RS232_address:=RS232(COM_number);
     writeln('RS232 address: ', RS232_address);
     dummy:=Configure_RS232(RS232_address);
     clrscr;
     repeat
     Writeln('A/D converter configuration, dual channel');
     write('Input output byte (0-127, 255 to quit): ');
readln(out_byte);
     dummy:=AD_converter(rs232_address,1,out_byte,0);
     writeln('Voltage at channel 1:
',AD_converter(RS232_address,1,out_byte,0)/4096*5.02:5:3);
     dummy:=AD_converter(RS232_address,2,out_byte,0);
     writeln('Voltage at channel 2:
',AD_converter(RS232_address,2,out_byte,0)/4096*5.02:5:3);
     writeln('Input digital byte  : ', inputdata(RS232_address));
     writeln('Press Return to continue...');readln;
     clrscr;
     until out_byte=255;
end.
```



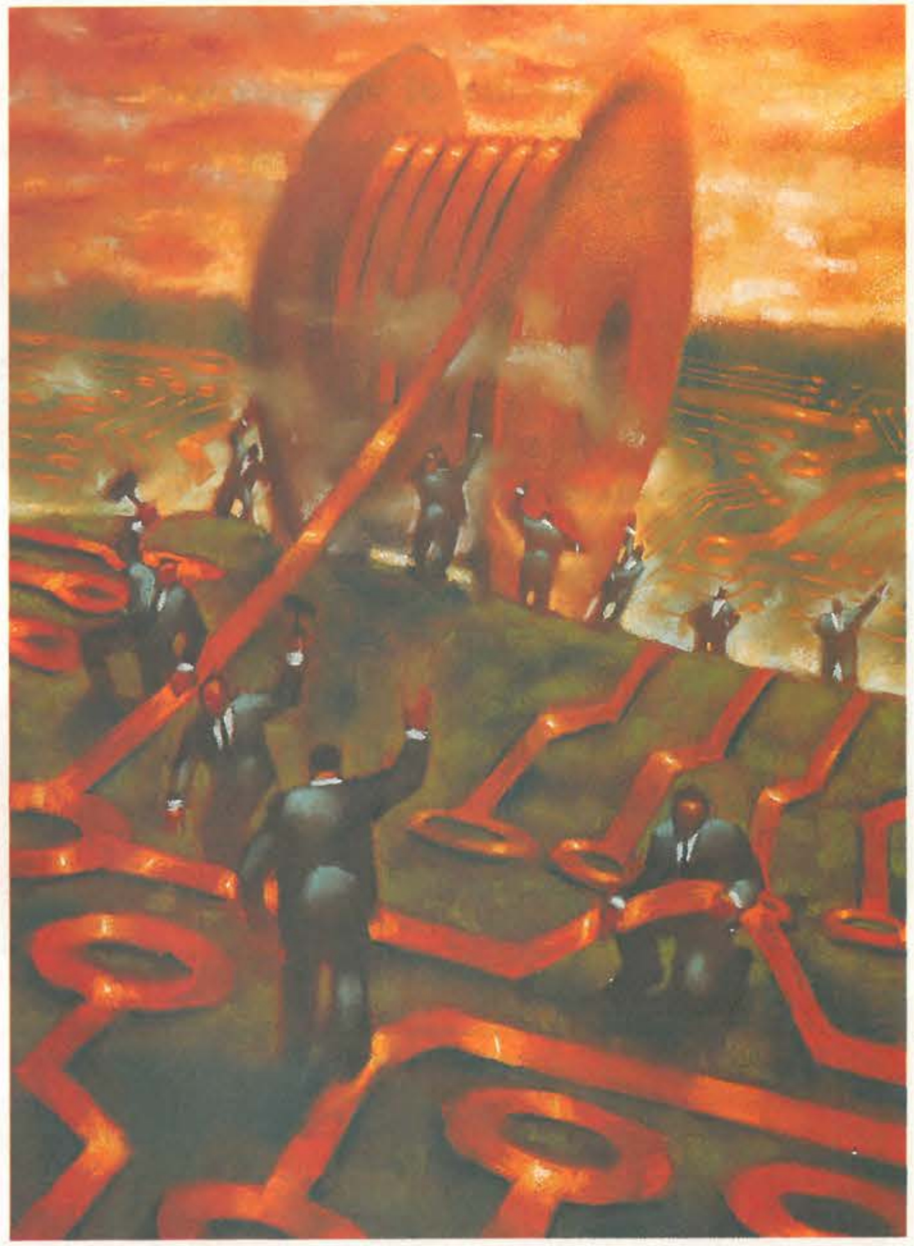


ILLUSTRATION JAMEL AKIB

Rod Cooper describes different methods for translating the CAD prototype layout you see on screen to copper tracks on a pcb.

Prototyping circuit boards

Designing your pcbs with the aid of computer software offers some unique benefits when it comes to transferring the track layout to copper. One benefit is the ability to produce files for photoplotters and numerically-controlled drill machines.

Most small firms or individual designers using a budget-price computer-aided design program will not be contemplating making their own pcbs in production quantities, so for many designers, the route to making a pcb will end here when they turn over these files either to a pcb manufacturer or to one of the many Gerber photoplotter bureaux.

Prototyping, on the other hand, is a very different matter. It does not make sense to have your autorouter turn out the artwork for a pcb in a flash if you then have to wait for hours or days for some third party to make up a prototype pcb for you, especially if the original design has to be corrected two or three times due to mistakes or last-minute design changes.

The alternative is to make your own trial boards.

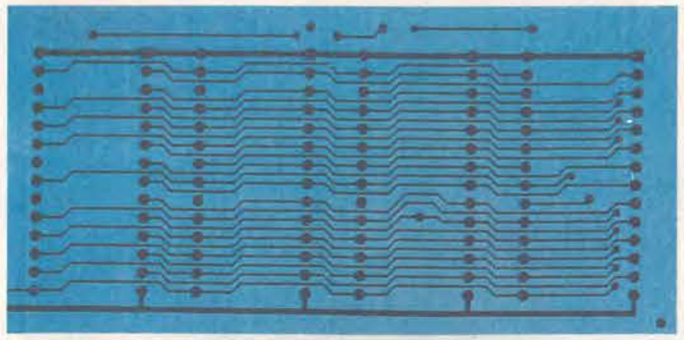
For many, this is not a likable prospect, because the conventional ultra-violet methods that most readers will be familiar with are messy, slow, and give uncertain results, but there are several techniques for making the process more amenable which are discussed here, some of which are specific to pcb-CAD.

It must be emphasised that none of these methods will give results quite as good as those produced by a photoplotter, but for prototyping they can be very acceptable.

Printing versus plotting

The starting point for prototyping is usually a print on paper or a transparency made on the pc's printer or plotter. This must have a dense,

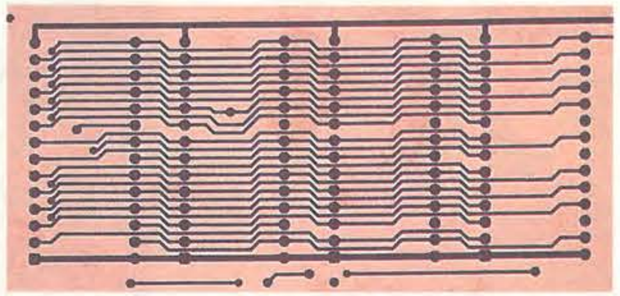
Examples and results of various ways of applying of etch resist



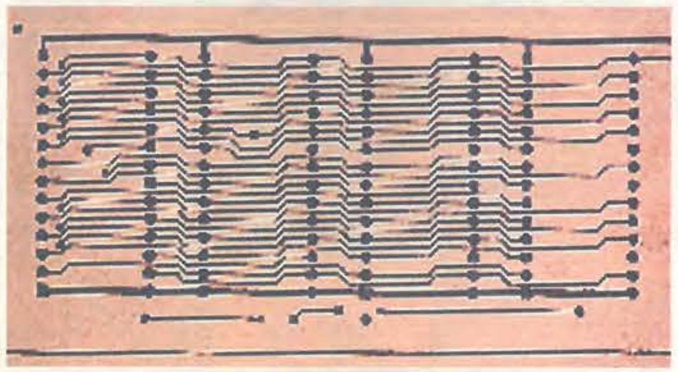
An image printed onto PnP with a laser printer.

Plotting with a 0.3mm pen directly on to 0.35mm copper board. Note that the board is clamped on the left-hand side and held flat on the right using masking tape – not the usual magnetic strip.

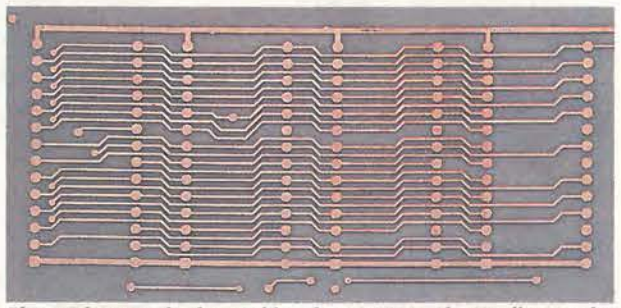
After being passed through a pouch laminator, the PnP sandwich is peeled off by hand.



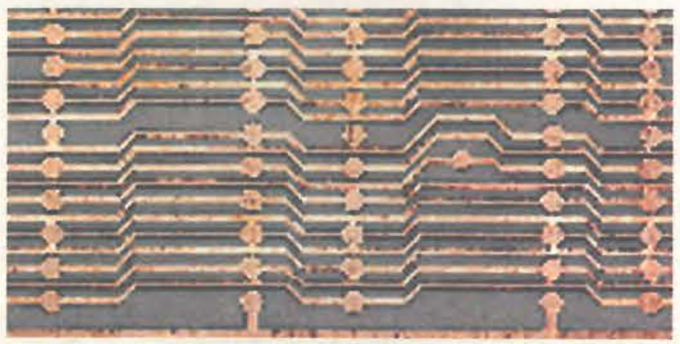
Pen-plotted tracks before etching. Compare this with the quality of the board prepared using PnP.



Appearance of copper board board with PnP image before etching. Note the the edges of the track are not quite so clear as those from the pen plotter.



Plotter-drawn pcb after etching demonstrates that outline results are as good as they were with PnP, but there are no small copper spots caused by toner contamination.



Close-up of PnP-printed board after etching reveals a few spots of unintentional copper and a slightly ragged edge, caused by toner contamination during laser printing.

(a) (b) (c) (d)

Results of plots made with various inks intended for overhead projector work are shown in a), b) and c). Very poor etch resistance is indicated. Plot d) was produced using proper etch-resistant ink. Not shown is a further plot produced using waterproof Indian ink: the copper was completely etched away.

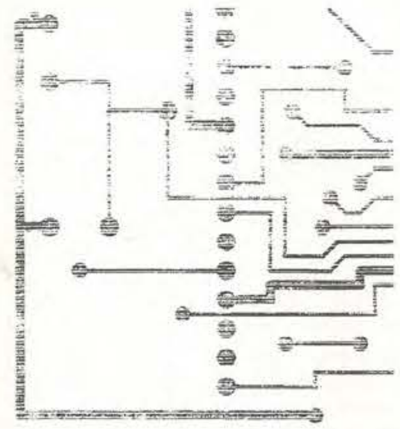


Fig 1. Dot matrix printers and, to a lesser extent bubble jets, tend to cause banding on the print out, with light and dark streaks running in the direction of the head travel.

even, image if it is to be successful. Printer artwork that looks fine to the naked eye is often exposed as being riddled with defects when it comes to etching. Etching reveals all. However, good artwork is not difficult to achieve in practice if a few basics are observed.

Suggestions are sometimes made in CAD manuals that dot-matrix impact printers can achieve the necessary standard, but these printers suffer from the banding effect, **Fig. 1**, and lack of density. One school of thought says that with impact printers, the density problem can be temporarily solved by putting in a new ribbon. But another school says that doing this results in loss of definition and accuracy. They are both right, so for pcb-CAD the dot-matrix impact printer is in an impossible position.

Bubble-jets perform better, but they can also suffer banding and the definition can be less than acceptable. Bubble-jet transparencies are not always a great success because the ink is not inherently compatible with plastic film, although big strides have been made recently to improve this.

It can be difficult to see a break in a track caused by banding on a 1:1 bubble-jet print or transparency with the naked eye, but the break will be faithfully reproduced on etching. Such breaks can be seen under 10× magnification, so it pays to look very closely even when the print seems fine.

In addition, ink bleed on bubble-jets can give spidery ragged edges to tracks and pads – even when using proper ink-jet paper. Ink bleed is a potential source of shorts on the finished pcb if tracks are closely spaced.

Bubble-jet tip

A much better method with a bubble-jet is to make an enlarged plain paper print of the artwork, then reduce it to the right size with a photocopier onto overhead projection film or the PnP material described later.

Most CAD programs offer an enlarged-print option for this very purpose. The image so produced is usually more crisp and dense than the original if the photocopier is well-maintained, and this technique nearly always gets round the shortcomings of the bubble-jet.

Be warned, though, that most photocopiers do not copy accurately. They need to be regularly adjusted for separate dimensional accuracy in width and breadth due to wear and tear on the mechanical parts of the optical and the paper transfer systems. Copier service engineers carry the necessary charts and have the adjustment procedures at hand, but in my experience, they rarely use them because the adjustments are time consuming. If you want to use a copier for this or other pcb processes, you must get it calibrated.

Best results from plotters

In contrast to dot-matrix printers, the image made by some laser printers can be sufficiently dense and well-defined for use as pcb artwork.

However, the best artwork in my experience is produced on a flat-bed pen plotter, **Fig. 2**.. There are special plotter pens and inks for producing ultra-deep black images on both plotter paper and plotter transparency film. Such a pen is the Staedtler *757 PL* type, which has a tungsten carbide tip. This pen has a groove cut in it for increased ink flow, which improves image density.

These pens are refillable and can produce lines as fine as 0.13 mm (about 0.006in), with excellent definition when the right speed (<25mm/s) and downforce (0.2N to 0.3N) is used.

The recommended ink for the pen mentioned above is quick-drying Indian ink Staedtler type *747T*, for use on glossy plotter paper or matt polyester film. It is tempting to use other sorts of pen such as sealed fibre-tipped and roller ball type because they are much cheaper and the results can be acceptable, if not quite as good.

When a pen plotter is used with transparent material the artwork is often good enough to be used for a direct 1:1 contact print. But if you want even better definition – for surface-mount boards with fine tracks and close spac-

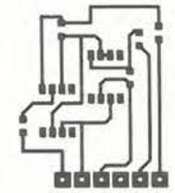


Fig. 2. Actual size of a surface-mount board showing that plotters are capable of fine detail.

ing for example – plotters can be used to print an enlarged image onto plain paper for subsequent reduction on a copier. Most plotters can handle A3 format paper.

Regrettably, none of the Windows programs reviewed had plotter drivers that performed well when used with Windows 3.x. For pen-plotting pcb artwork, control is needed over pen speed, width, pen selection and preferably down-force as well. Sometimes, a fifth variable, namely the pen acceleration rate, can also be adjusted.

Unfortunately, even those Windows programs that had their own driver in place of the Windows 3.x driver did not offer the basic four adjustments. Some Windows drivers were erratic in operation and/or very slow to load programs. In contrast, the plotter drivers in the dos programs all performed adequately.

The best was that of *Ranger2*, which offered all four basic adjustments in an easy-to-use full-screen menu, but *Easytrax*, *Traxmaker*, *EasyPC* and *Proteus* all gave good results.

My guess is that the standard Windows 3.x plotter drivers were not intended for CAD use. I am informed that in Windows 95 the plotter drivers are much improved.

Which pen size?

Confusion may arise over units of measurement used for plotters. Plotter pens are sold in metric sizes and are often marked with just a number, 0.3 for example, which indicates a nominal width of 0.3mm.

But many pcb-Cad programs still use inches as their primary units. As a result, a pen width may appear on-screen as a bald figure of 13, it being taken for granted that this refers to 13 thousandths of an inch, or 13 mil. This actually corresponds to a 0.3mm pen.

Because of this mixture of units, you need to read the CAD manual carefully. Certain programs, such as *Proteus*, offer a choice between metric and imperial units.

Photocopiers for pcb work

The following photocopiers are relatively oil-free when used with a microsleeve pressure roller;

Make	Mita	Triumph-Adler	Utax	Nashua
Type	DC1205	TA 2012	C105	8112
	DC1255	TA 2212	C106	8112RE
	DC1656	TA 2216	C144	3916

On these particular machines, it is a simple task to replace the old roller.

Arranging the usual serial connection for plotters can be very time-consuming and it is much easier to go for a parallel connection if this is physically possible. I used a parallel connection for the plotter tests on the programs reviewed.

Transferring artwork to copper

The conventional process of making a contact print using ultra-violet exposure and pre-coated photosensitive copper-clad boards, and then developing the image in a chemical bath, is messy and slow and the results are far from guaranteed. With alkali developers, skin and eye protection is necessary.

However, the main objection is that the results are so uncertain. Ultra-violet exposure rates vary from batch to batch and between manufacturers of the sensitised boards. As a result, exposure is hit and miss. You can perform a timed test beforehand on a spare piece of laminate each time you buy some material, but this is very time-consuming.

Development is also a randomly variable process so it's mainly a matter of luck if a board turns out well without prior experimentation. The penalty for incorrect exposure and development times is a wasted board, which can be expensive. You never know for sure if the board is sound until the etch is over. If it isn't sound, you have to use up even more valuable time repeating the process.

It is not surprising that this part of prototyping pcbs is disliked. Unfortunately, the ultra-violet method is the only process on offer from the major suppliers of materials such as RS and Farnell. But there are viable alternatives.

Alternatives to ultra-violet

A few years ago it was realised that laser printers and photocopiers had good potential for assisting the transfer of artwork onto materials other than paper. This has led to products designed specifically for use with pcb-CAD.

In one process from the DynaArt Designs company, which takes advantage of this ability, the artwork is produced on a special film fed into the pc's laser printer. This special film with the artwork impressed on it is then simultaneously heated and pressed onto the copper board material either with a domestic iron or a pouch laminator.

On cooling, and after soaking in water, the film is peeled off, and the black toner outline of the artwork stays on the copper. The board can then be etched in the usual way.

The concept of a print from the pc to a laser printer and then straight to copper is attractive as it is so direct. Such a film could also be used to transfer the artwork to the copper indirectly with a photocopier, using a plain paper print of the artwork as the original and feeding the special film through the copier's by-pass tray. The big advantage here is that a large-size original could be reduced to actual size to improve definition.

The process depends on the fact that toner for laser printers and copiers is usually based on powdered acrylic styrene polymer formulas. These melt at around 120 to 150°C to form a gum with good adhesive properties. The actual melting point depends on the brand.

What to watch out for

There are a few snags with this process. First, the photocopier or laser printer has to be in perfect condition. Any fading of the image means that tracks are etched where they should not be, and any defects in the photocopier, such as drum scratches, drop-outs and streaks, are faithfully copied onto the artwork.

Secondly, ordinary toner is not all that etch-resistant and this property varies considerably between different manufacturers. It has to give a dense black uniform coating to the artwork for good results and this partly comes back to the condition of the photocopier.

Unfortunately, the modern trend away from selenium/arsenic photoreceptors and towards the organic type does not help. The selenium/arsenic drums could be relied on to give good, black, toner-rich images with excellent contrast. The organic drum on the other hand is inclined towards producing shades of grey.

Although special dense 'art' toner cartridges have been put forward for laser printers to solve this difficulty, this means diverting the laser printer away from its basic function as a piece of office equipment. But if you want to use this process, my advice is to use one of these dense cartridges.

DynaArt supplies a complete system – the film, art-grade toner cartridges for laser printers, and suitable laminators.

Etching tips

With most of these prototyping methods, the etch resistance of the artwork is not as good as that on the professionally-made product.

Results will be disappointing if some basic steps are not taken. The first rule is that the faster the etch, the better the performance of the artwork material, whether it is plotter ink or *PnP*. If the etch takes longer than 20 minutes it is too slow. For a fast etch, the solution must be heated, but not too much. For ferric chloride, 35°C is about right and 45°C too high.

Secondly, the etch process must be even. If the solution is not agitated constantly then the copper at the board's periphery will be etched first, then over-etched to failure long before the centre of the board is properly etched. This is probably the main cause of complaint with the prototyping systems described.

You cannot get away with the occasional stir; constant agitation is essential and the only way to get consistent good results is by mechanical agitation. This could be provided by an adapted electric food mixer with plastic paddles, a low-voltage aquarium aerator pump blowing bubbles of air through the solution, or motorised tilting of the etch bath. My own favoured method is the adapted food-mixer as this gives good agitation and also aerates the solution, which increases the efficiency of etching. It is also cheap and readily-available.

Needless to say, if you leave a mechanically-agitated system unattended, a timer alarm is vital.

Technical support – suppliers

Plotter pens – Steadtler (UK) Ltd, Pontyclun, Mid Glamorgan CF7 8YJ, tel. 01443 237421 (pens can be ordered through Steadtler retailers).

Art toner cartridges, laser transfer film, DynaArt Designs, 3535 Stillmeadow Lane, Lancaster, CA 93536-6624 USA, tel. (001) 805 943 4746

Thin copper laminate (in bulk) Crossley & Bradley, Ulnes Walton Lane, Leyland, Preston PR5 3NB, tel. 01772 452236.

Pouch Laminators suitable for use with PnP film, Anmron Ltd, 49 Gorsty Hill Road, Rowley Regis, Waley, West Midlands, tel. 0121 559 7738.

Etch-resistant plotter ink, PnP film, thin pcb material (small quantity) Verkonix Ltd, PO Box 6145, Sutton Coldfield B73 5PX, tel. 0121 354 5569.

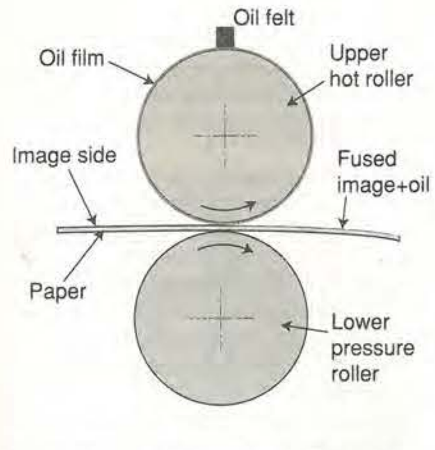


Fig. 3. Silicone oil contaminates the image side of material such as paper and other media put through the photocopier.

For better results...

A material called *PnP* gets round some of these problems by using the toner only as a glue for a more substantial etch-resistant overcoat. This material comes in flexible blue plastic sheets the same thickness as standard 80g/m^2 copier paper, and is designed to be fed through either a laser printer or photocopier just like paper.

After going through the copier or laser printer, the image of the artwork appears in black toner against a blue background. The sheet is then pressed image side down onto the copper board via a pouch laminating machine or by careful use of an domestic iron. The application of heat and pressure causes the toner to fuse to both copper and the blue *PnP* coating. When the sheet of *PnP* is removed by peeling it off, the artwork remains stuck to the copper as a deep blue image.

Etching can then follow in the normal way. Because the toner acts merely as the adhesive for the etch-resistant overcoat, the etch-resistance of the image is not dependent on toner type or image quality. Good results can be obtained on the average photocopier or laser printer – although scratches on the copier drum etc. will still be reproduced.

Laminating machines are designed for use with thin card, so if you choose this method you will need very thin copper board in order for the sandwich of *PnP* and pcb to pass through the machine. With some laminating machines specially adapted for the purpose, slightly thicker board can be used.

Control of the laminator's speed and heat is essential to produce the right amount of toner fusion and thus a satisfactory transfer. In the trade, the speed setting is called the 'dwell time'. Some experimentation will be needed with the settings to get the right dwell time for a particular laminate thickness.

If you are using thin copper board, it has to be bonded onto a plain grp board to make a board of normal thickness, compatible with pcb components – Nylon stand-off pillars for example. Fast-setting epoxy adhesive is suitable for this. It is better to increase the board thickness before etching, because thin boards tend to warp badly in aqueous solutions.

For prototyping, reasonable results with *PnP* can be obtained with just a little skill using a domestic iron. As a rough guide, if you can iron a shirt, you can use *PnP* down to track widths and spacings of 30 mil (≈0.7mm).

If you can iron a shirt...

With an iron, you are not restricted as you are with a laminator by the overall size of board it can handle. In addition, you can use standard-thickness pcb material. However, laminators give much more consistent, reproducible results.

There are snags to *PnP*. Although the literature claims that copper tracks less than 5 mil can be reproduced, I have found that some considerable skill is needed to achieve this with an iron, so a laminator is more or less essential at this scale.

Secondly, many laser printers and photocopiers use silicone oil as a release agent on the hot roller of the fusing section. **Fig. 3** shows how this oil is applied. On some machines, there is no oil felt, but the lower roller is impregnated with silicone oil during manufacture to produce the same effect.

The purpose of the oil is to stop the paper sticking to the upper hot roller, which usually has a ptfe coating to assist this process. Inevitably, some oil comes off on the image side of the paper. The film of oil is so thin that it is not normally noticeable on plain paper. With *PnP* and similar products like DynaArt's however, the presence of even minute quantities of such a release agent has a big effect on how well the image sticks to the copper laminate.

The best photocopiers for this use have no oil at all in their fusing sections. On these machines, the hot roller relies solely on the ptfe coating to prevent sticking. The pressure roller has a thin, non-stick, coating called a Microsleeve*, instead of being impregnated with oil. A short list of some of these machines is given later.

By using this system, prototype boards can be made in a fraction of the time of the ultra-violet method, without the mess of developer chemicals. Indeed, as most photocopiers can turn out 20 or more copies a minute, the *PnP* system is so fast it could be used for a short production run if you have a pouch laminator as well. There is no waste of copper board at the imaging stage as there is with the ultra-violet process; if you don't like the artwork for any reason you can wipe it off with acetone and within minutes you can imprint a fresh image.

The other benefit of using these photocopier-based materials is that published pcb layouts can be photocopied straight from magazines and books.

Plotting on copper

A flat-bed plotter provides the most direct method of all for getting the artwork from the CAD screen onto the copper laminate. It is also has the lowest production costs, but the capital outlay is higher.

The pens with grooved tungsten-carbide tips mentioned earlier are suitable for plotting onto a copper surface, but they are expensive, at about £50 each. If you use a piece of copper board the correct size for your finished board but smaller than the plotter's set area, of A5 or A4, etc, any mis-plot may result in your expensive pen tripping over the edge of the board and breaking.

It always pays to make several trial plots on paper or card first to reduce the risk. Alternatively, you can use a much larger piece of laminate so that the pen never comes anywhere near the edge.

It is also highly desirable to have control over the pen down-force. These pens have a rating of 0.1 to 0.3N. The plotter's default value may be alright for plotting on paper and film, but far too high for copper. On thin laminate, the impact will dent the surface. This may even appear as a bump on the reverse side.

Of the programs reviewed[1], only the *Ranger2* plotter driver provided a control for pen down-force. However, if your chosen CAD program has no downforce adjustment and you don't object to modifying your plotter, it is not too difficult to put a variable resistor in series with the pen solenoid circuit to control down-force directly. I have done this on my own plotter.

Achieving the best resolution on a plotter – 0.001in on most machines – depends greatly on the skill of the operator in getting the right set-up. For example, if you are using standard thickness laminate, the plotter pen will be cocked up at an angle and the ink will flow unevenly. Etching will then quickly reveal where the ink is too thinly applied.

Using thinner laminate and putting a piece of self-adhesive packing on the pen holder to make it upright will cure this without upsetting the mechanical configuration of the plotter too much. I use 0.35mm thick laminate and this technique works fine. Some adjustment of down-force may be necessary to compensate for the new working angle of the pen.

It is sometimes stated that pens used for plotting on overhead-projector film with oil or spirit based inks have etch resistance. This is only partly true.

*Microsleeve is a trade mark of Katun UK Ltd. The Microsleeve roller is available from Amron and some photocopier service firms.

Results of ink etch-resistance tests

In the last figure in the panel, I tested three such inks from well-known suppliers. These are labelled a), b) and c). As a control, I plotted in a waterproof Indian ink. To challenge the properties of the inks the test artwork was given a fine spacing, a couple of thin tracks and a solid area.

As the results of etching show, none of these inks had good etch-resisting properties. The waterproof Indian ink had no etch resistance at all. In contrast to this, board d) shows the test repeated with an ink designed specifically for etch-resistance. The results with this ink were consistently excellent.

One thing a plotter can do which printers and photocopiers cannot is to overcoat the artwork several times. Plotters can easily repeat the same artwork very accurately if the copper laminate is kept in exactly the same place on the platen. The first plot could be made in an ink with good adhesive properties on copper, which could be followed when the first ink had cured with an ink that had good etch-resistance, and so on.

For the second pen, careful choice of nib material is needed to avoid damage to the first coat. A metal pen nib will scrape and tear the first coating, so a softer nib is needed. Control over the pen down-force then becomes even more important. Final artwork produced by this method is highly resistant to etching solution.

Pen plotters have considerable potential for plotting artwork in conductive ink. This could be very useful for prototyping smd boards, as **Fig. 2** shows. Clearly, pen plotters are sufficiently accurate for surface-mount work, but it certainly helps the plotter if the autorouter has a track-spreading option to avoid closely-spaced continuous tracks. The *Specctra* autorouter is the only one of those reviewed that could do this.

Components are glued onto the pads with conductive epoxy (RS 496-265 for example). However, I have found no no commercially available conductive inks or pens that have been developed for plotter use, although there are conductive inks on the market in pens for hand application such as the *Circuit Works 2200*. Perhaps this will change in the future if there is a demand.

Pen plotters are expensive compared to printers, but they are more versatile and their running costs are low – a little ink goes a long way. You need only the bare copper laminate, which is much cheaper than either photosensitive board or *PnP*. In my experience, plotters are inherently more reliable than laser printers, having fewer moving parts to go wrong, and no need for heat or pressure devices.

As with the *PnP* method, there is no waste of copper board if you make a mistake – the artwork can be removed with acetone and the laminate re-used immediately. On the other hand, as plotting is slow compared to *PnP* it is unlikely to be useful for a short production run. ■

A robust 500V dc power supply with current limiting, thermal protection and an output capabilty of 50mA, designed by Richard Lines.

High-voltage supply

High-voltage power supplies are something of a rarity nowadays; this note describes the circuit for an adjustable 500V at 50mA power supply having both voltage and current regulation.

The circuit was originally designed to power a gas discharge lamp in constant-current mode, so as to provide a stable light source. But it is equally suitable for powering avalanche photodiodes or valve circuits.

Stability and regulation are good; the residual ripple at 50mA output is only a few millivolts and the output voltage is held constant to better than 0.1V indefinitely. This design would make an excellent power supply for a valve preamplifier, and with minor modifications could be used for driving a photomultiplier.

Cicruit operation

The high voltage is produced from the secondary winding of the mains transformer T_1; the 250-0-250V rms is fed to a bridge rectifier $D_{13\text{-}20}$. Output from the bridge is smoothed by two 47μF capacitors, namely $C_{31\text{-}32}$, to give about 700V dc prior to regulation.

Note the use of eight diodes in the bridge rectifier. This ensures that the reverse breakdown volts rating of each diode is unlikeley ever to be exceeded. Parallel capacitors $C_{23\text{-}30}$ make sure that the reverse bias is shared equally between the diodes even if the leakage currents are not matched.

The only smoothing capacitors to hand when I designed the circuit were rated at 450V so I used two in series: again it is necessary to fit voltage sharing resistors to make sure the 450V limit is not exceeded.

Voltage regulation is carried out by series pass transistor Tr_1, which is a high voltage power mosfet type *BUZ357* made by Siemens. The circuit takes full advantage of the freedom from secondary breakdown associated with mosfets; the positive temperature coefficient of the channel with temperature avoids the local hot-spotting which causes the high voltage problems associated with bipolar power transistors.

> **Warning**
>
> This power supply is a potentially lethal instrument. Read the article fully and carefully, especially the panel headed 'Safety and implementation'.

A large heat sink is still necessary since the transistor would be dissipating 35W if the power supply is accidentally run into a short circuit at maximum current.

Voltage is regulated as follows; a constant current is generated by the circuitry around Tr_2 and IC_{2c}, appearing at the drain terminal of Tr_2. This current is proportional to the required output voltage and can be varied between zero and 50μA.

The current is passed through the sampling resistor chain $R_{1\text{-}11}$, over which the required output voltage is developed. When the output voltage is correct the potential at the two inputs of error amplifier IC_{1a} will be the same and the output of this op-amp forward-biases Tr_1 just enough to maintain the required output voltage.

Note that all the control circuitry uses the *positive* output terminal as the local reference and return. It is the potential at the negative output terminal which is sampled using the constant current through $R_{1\text{-}11}$.

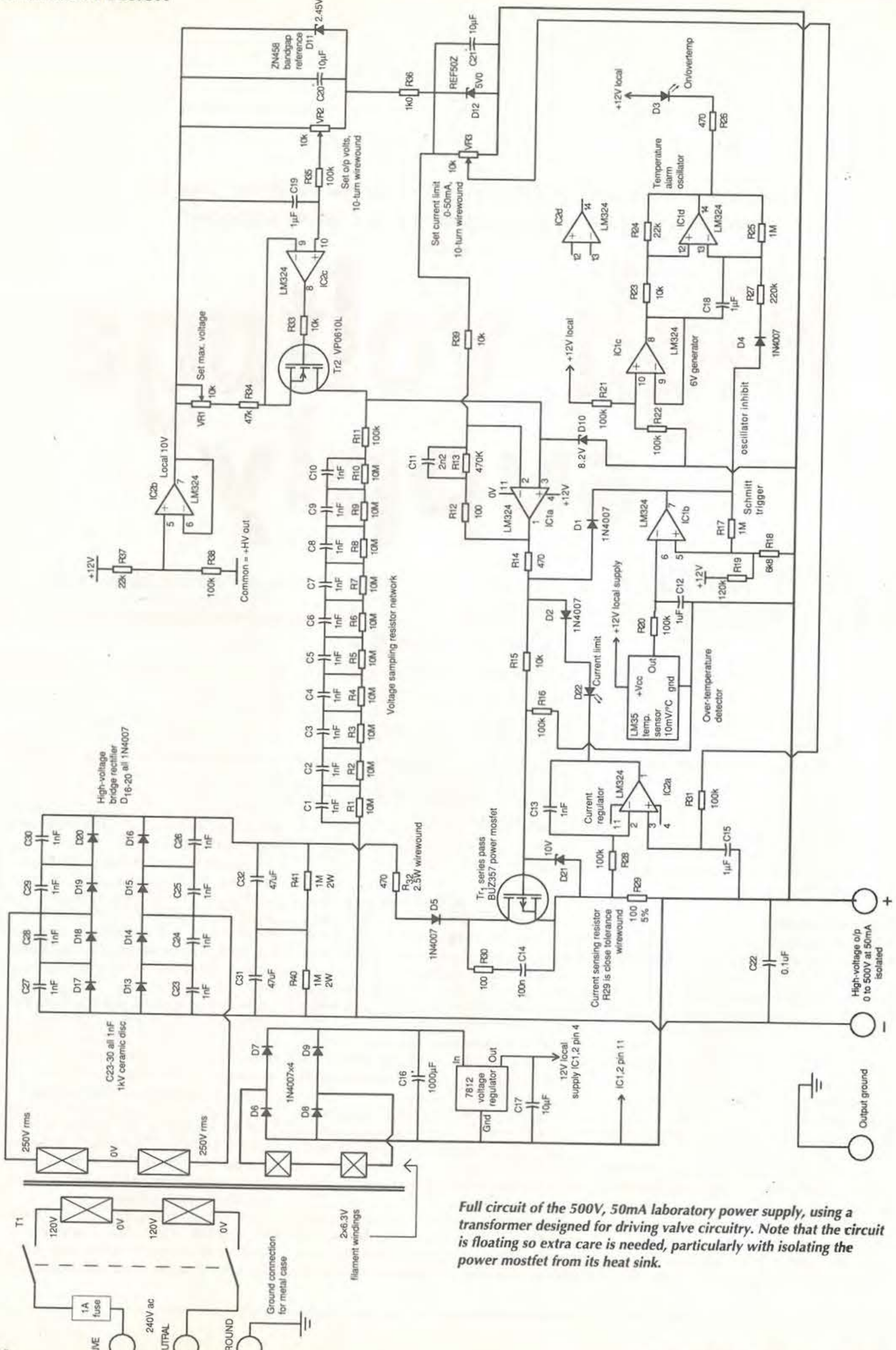
If the output is too high, i.e. the potential at the negative output terminal is too negative, then pin 3 of IC_{1a} fall with respect to pin 2. This error is amplified and results in less forward bias being applied to Tr_1. Conversely if the output is too low, IC_{1a} sees the error and apply more bias to Tr_1.

A straightforward potential divider could have been used to sample the output, but a lot of loop gain would have been lost. If the impedance at the drain connection of Tr_2 is infinitely high, as for a perfect current source, then voltage errors are passed unattenuated to the error amplifier, resulting in better regulation.

The current source is powered from a local 10V supply provided by IC_{2b}. This avoids common-mode range problems with the op-amps. Trimmer potentiometer VR_1 sets the maximum output voltage.

Current regulation is achieved by the circuitry centered on IC_{2a}. Output current is sampled by measuring the voltage across the 100Ω resistor R_{29}. This voltage is compared with the user-chosen limit set by VR_3, which can be varied from 0 to 5V, corresponding to 0 to 50mA output current.

For currents below the limit the output of IC_{2a} approaches 12V. This means diode D_2 is reverse-biased so the current limiter has no effect on the voltage regulation. As the current



Full circuit of the 500V, 50mA laboratory power supply, using a transformer designed for driving valve circuitry. Note that the circuit is floating so extra care is needed, particularly with isolating the power mostfet from its heat sink.

threshold is exceeded the potential at the output of IC_{2a} falls and D_2 conducts, removing the forward bias to Tr_1. At this point the voltage regulation is lost and the high voltage output falls to whatever value that will maintain the current limit through the external load.

A measure of thermal protection is provided by a *LM35D* temperature sensor fitted to the heat sink. The sensor produces an output of 10mV/°C. This is connected to a schmitt trigger set to change state at approximateley 60°C.

When the trigger changes state, gate bias to Tr_1 is removed via D_1 until the heat-sink cools down. Resistor R_{17} provides a small amount of hysteresis to the trip point, and a flashing overtemperature warning is provided by IC_{1d}.

My original circuit was prone to oscillation, so some frequency compensation was added in the form of C_{11}/R_{12}, C_{14}/R_{30} and C_{13}. The series capacitor chain $C_{1\text{-}10}$ removes the effects of an unwanted pole in the feedback loop formed by $R_{1\text{-}10}$ and stray capacities.

Previous incarnations of this power supply have used bipolar transistors of the *BU500* variety as the series pass transistor. Components D_5 and R_{32} were found to kerb an excessive mortality rate when the power supply was accidentally short-circuited in these earlier versions. They were necessary because the current limit did not act fast enough to prevent breakdown.

Protection components D_5 and R_{32} may not be necessary with the mosfet design. I have left them in since the added expense is very small. To date I have had no failures.

A conventional 12V local power supply is taken from two 6.3V filament windings wired in series.

Component notes

Mains transformer T_1 was purchased from RS Components . It is still listed in the latest catalogue but will not be available when present stocks run out. A quick scan through the catalogues has not revealed a direct replacement but there are a few alternatives.

First, Maplin advertises a 600V rms at 25mA laser transformer which would be suitable if your application can tolerate the reduced current rating. However there is no 12V winding so a separate transformer would be needed to power the control circuitry.

Secondly, an isolation transformer could be used. These are available from several suppliers in a range of wattages; a 50VA component would be suitable. This solution requires the high-voltage bridge rectifier to be changed for a voltage doubling arrangememt Again, there is no 12V winding included.

Ratings of the series-pass mosfet, again from RS are 1000V and 5A – but not at the same time. There are other transistors of similar ratings available. The following have not been tried but should be satisfactory: *2SK1357, BUZ312, BUZ50A, BUZ51 and BFC51.*

Capacitors C_{14} and C_{22} are polypropylene types rated at 1000V. Diodes D_{11} and D_{12} are both bandgap references and are easily available: D_{12} could be substituted with a cheaper zener diode with some loss of stability. Transistor Tr_2 can be substituted with a high gain p-n-p transistor of the *BC307* variety but the use of the p-channel mosfet eliminates entirely the small error term resulting from the bipolr device's base current.

Some comments are necessary concerning the behaviour of resistors when connected to high voltages. You may wonder why it was necessary to use ten resistors in series for $R_{1\text{-}10}$. The reason is that physically small resistors with high values tend to age rapidly when connected across a high voltage. This is not because the power dissipated is above the official rating but because the electric field intensity tends to change the composition of the resistive track usually causing the resistor to change value.

Since $R_{1\text{-}10}$ form the voltage sampling resistor chain, these components need to be stable with temperature changes; the temperature coefficient of metal-oxide resistors is generally

Safety and implementation

It should go without saying that with potentials up to 700V some thought is required to ensure that the finished unit is as safe as possible. This is especially true if the unit is to be used by those having little experience of electrical hazards.

I suspect that many of you will have limited high voltage experience, other than wiring up 240V mains, so a few pointers may be in order. Apologies in advance to the old hands.

All of the internal circuitry is isolated from the case and ground thus allowing operation as a floating, positive or negative supply depending on which output terminal is connected to ground at the output terminals.

The case should be metal and securely earthed. Should ventilation holes be required then they should be small enough and so located that fingers, screwdrivers, pieces of wire, etc cannot be inserted and touch the dangerous points. This may entail fitting extra perspex covers over transformer connections and group boards. Heatshrink can be fitted over the high voltage connections on the fuseholder, on/off switch and transformer terminals.

The heat sink needs some consideration; it is obviously essential to ensure a free air flow around the fins. The easy way to achieve this is to mount it on the outside of the box. If this is done the heatsink will be earthed and the insulation to T_1 must be very good. I do not trust a normal insulating mica washer. I managed to obtain a special high voltage thermally conducting one.

If such a washer cannot be found, an alternative arrangement would be to bolt the transistor to the heat sink without a washer. The complete assembly is then mounted on insulating pillars inside the metal case. It will probably be necessary to include ventilation holes and a fan.

A few baffles can now be used to direct the flow of air and also to block access via the holes to the danger points.

The output terminals are an obvious source of danger. On the prototype, a small diecast box bolted to the front panel was used to enclose the terminals. Connecting wires to the load are passed through a small hole in the side of the box and screwed to the terminals. The lid is then fitted so there is no possibility of accidentally touching the output.

As it stands my supply offers no protection if the lid is left off. If the design is to be used by students, then it would be wise to add some sort of microswitch arrangement so the supply is disabled the instant that the cover is removed.

If you make a printed circuit board, it is wise to leave plenty of clearance around the high voltage tracks; one centimetre is adequate. Veroboard is not recommended. The board is best mounted on nylon pillars to the case.

Potentiometers $VR_{2,3}$ can be a source of trouble if they have a metal shaft and case. To avoid arcing over, it may be worth mounting them on a Perspex plate inside the box and using a plastic shaft and coupler to connect the knob to the potentiometer. Thus the metal case of the potentiometer is completely isolated.

Voltage and current meters can be fitted as required, but bear in mind that the front covers of some meters are easy to remove, allowing access to metal at high voltage.

Smoothing capacitors $C_{31\text{-}32}$ were wire-ended types with the body insulated. I have seen other chassis mounting types available where the metal case is not always isolated from the negative terminal. If in doubt, add extra insulation.

The 'power on' and 'current limit' leds need extra insulation; don't just glue them into holes drilled into the front panel. The *LM35* temperature sensor is recessed into a 4.8mm hole drilled into the heat sink next to Tr_1.

Again, take care the leads cannot touch the metal, especially if the transistor is not isolated from the heat sink.

And finally, don't forget to take similar safety precautions with whatever load is being driven by the power supply.

better than for carbon types. At 50V maximum, the voltage dropped across each resistor is low enough to avoid the ageing effect.

Resistor R_{34} should also be a 1% close-tolerance type with a low temperature coefficient. This is because changes in the supposedly constant current will directly affect the output voltage.

The 1MΩ resistors used in the bridge rectifier and across the smoothing capacitors should be 2W carbon types.

Current-sampling resistor R_{29} needs to be a 2.5W wire-wound component if stability of the current limit is important. Wire-wound types generally have a low temperature coefficient and will run cooler if over-rated. If you only need to use the current limit as a safety device then a 1W carbon component is fine.

Front panel controls $VR_{2,3}$ were ten-turn wire-wound potentiometers. These give very smooth operation and allow precise setting of current and voltage.

Other quad op-amps can be used, but the input common mode range needs to extend to the negative rail. The temperature sensor is sold in two grades, LM35C and LM35D. The cheaper D version is adequate.

The output terminals should be such that there is plenty of clearance to the metal case. 4mm binding posts were used in the prototype.

The heatsink needs a thermal resistance of 1 to 1.5°C/W. Both RS and Farnell both stock a suitable selection. If space is at a premium then a smaller heatsink can be used in conjunction with a small fan.

Setting up and use

A voltmeter or multimeter equiped with test leads terminated in small insulated crocodile clips is useful since they allow the meter to be connected with the circuit switched off. Thus measurements can be made without having to hold a probe inside the circuit.

The usual advice is to keep one hand behind your back and stand on a rubber mat when working on exposed high voltage circuitry.

A dummy load consisting of a 10kΩ resistor rated at 25W is required. This was made from three 33kΩ, 9W resistors in parallel.

Set both voltage and current controls to maximum and switch on with the voltmeter connected across the output but not the dummy load. The current limit led should be out, and the on/overtemperature led permanently illuminated.

There should be approximately 500V, which is adjustable with the control. Using a long plastic trimming tool adjust VR_1 for 500V exactly at full output. Now switch off and connect the load in parallel with the voltmeter.

There should still be 500V if the circuit is regulating correctly. It is possible that the current limit will just come in; if this happens then backing off the voltage control should cause the unit to revert to constant voltage mode. The dummy load will become very hot so place it where it can't do any damage.

If all is well so far then leave the voltage set to 500V and reduce the current setting. The current limit led should light and the output voltage fall as the current setting is progressivley reduced.

If required, the supply can be tested into a short circuit. The current should limit to 50mA maximum depending on the setting. It is not recommended that the unit is used into very low impedances, although the prototypes have put up with accidental short circuits on many occasions.

If an oscilloscope with a high voltage probe is available, residual ripple and noise can be checked. At 400V across the dummy load, the ripple consists of a 100mV spike at 100Hz with no trace of the conventional sawtooth waveform. Random noise is at the 10 to 20mV level. Check the output at several settings and make sure there are no spurious high frequency oscillations.

These measurements should be done with the negative terminal of the power supply earthed at the power supply or an unwanted 50Hz signal will be seen.

The unit is now ready for use. ■

Colour tv goes public

Ray Herbert recounts events surrounding the first public demonstration of colour television in 1938.

On 4 February 1938, an audience of 3000 people watching a film at the Dominion Theatre in Tottenham Court Road, London had no idea that they were about to witness a piece of television history.

During the interval they were surprised to see live colour television pictures on a 12 by 9 feet screen, transmitted from a small studio at the base of the Crystal Palace South Tower. Advance publicity of the event had been impossible due to the restrictions imposed by the authorities regarding experimental wireless transmissions.

This was a highly significant occasion in two respects; never before had colour television been demonstrated to the public or transmitted by radio link – a double first for John Logie Baird.

Bearing in mind the many months of development work and the high cost of the sophisticated projection equipment, it is remarkable that no further demonstrations took place. A possible explanation is that Baird wanted to start work on a 600-line, high definition colour system and this he demonstrated in December 1940 (*Wireless World* February 1941).

Earlier experiments

It was typical of John Baird's zeal for immediate progress that he should attempt to produce television pictures in colour during 1928, at a time when improvements in the quality of the existing monochrome images represented the real priority. At that time he used scanning discs at the sending and receiving end which had 15 holes in three separate spirals, each occupying a third of the circumference and covered sequentially with red, green and blue gelatine colour filters.

The discs span at 600rev/min providing ten images a second. It was a relatively crude arrangement but the highly regarded journal Nature reported enthusiastically, "The colour images we saw in this way were quite vivid. Delphiniums and carnations appeared in their natural colours and a basket of strawberries showed the red fruit very clearly."

Having achieved a notable first, Baird moved on to the more prosaic problems of setting up studios and equipment for television broadcasts.

Colour updated

The later colour work carried out by Baird had it's beginnings at the Dominion Theatre in 1936 when he demonstrated his monochrome multimesh system. Whether by accident or

Supplying power

Power for the 150A arc lamp came from a Hackbridge Hewittic mercury arc rectifier and a frequency changer provided 100Hz for the synchronous motors.

A cubicle immediately adjacent to the colour projector housed the drive amplifiers and their associated power supplies. The final stage used two high power triodes in a patented, push-pull arrangement to deliver the 20000 volts peak-to-peak, necessary to exercise full control of the Kerr cell from darkness to full white illumination.

Twenty-faceted mirror drums for the mechanical colour camera and projector as used in for the Dominion theatre demonstration in December 1937 and February 1938. Photographed by Richard Brice.

design, it turned out that this arrangement could very easily be adapted for colour transmissions. This method was an elaboration of his earlier experiments with interlaced scanning in 1925. Then he used a scanning disc with two spirals of eight lenses so positioned that they produced an interlaced image. Fortunately, most of the apparatus survived and is in the Falkirk museum.

At the Dominion Theatre a 20-facet mirror drum in conjunction with a slotted disc provided a basic 40-line interlaced scan which was then repeated three times, in each case being laterally displaced to mesh with other fields to provide a final frame of 120 lines.

An arc lamp provided the illumination and a Kerr cell acted as a light valve to produce the necessary variations in light and shade. This arrangement had been used to good effect in 1932 to show large television picture of the Derby from the Epsom racecourse on the screen at the Metropole Theatre.

Baird only needed to place colour filters over the slotted disc apertures to convert this equipment into a two-colour television system.

The colour projector

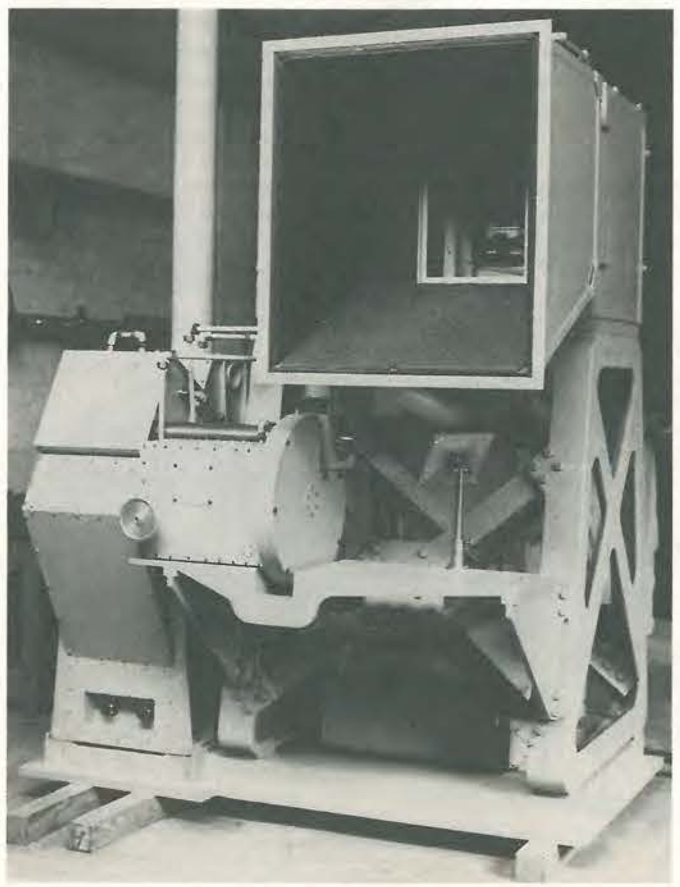
Ideally, the light path would have been in a straight line, but due to lack of space at the theatre behind the translucent screen used for back projection, this could not be achieved. Consequently, the light source, rotating colour filters and Kerr cell had to be housed in a separate cubicle at the side of the main mirror drum unit. This caused unwelcome complications in regard to the need for extra mirrors, an additional synchronous motor and mechanical phasing arrangements.

A 150A automatic searchlight arc lamp fulfiled the function of a constant intensity light source. Water cooling of the aluminium panels in front of, and above the arc, proved to be essential. A condenser followed by an intermediate lens, focused the light beam on to a disc having 12 slots covered alternately with blue-green and red colour filters. It then passed to the Kerr cell – a key component in the provision of large screen television pictures. Invented by a Scottish scientist in 1875 it consisted of electrodes immersed in nitrobenzine.

When polarised light from Nicol prisms traversed the cell, the intensity could be controlled by applying a variable polarising voltage to the electrodes. The higher the voltage the greater the illumination. In this installation the Kerr cell had just two electrodes to avoid loss of light and they were connected to a pair of transmitting triodes operating in push-pull. Due to the heat contained in the two-inch diameter beam of light, conventional Nicol prisms could not be used. They were replaced by polarising prisms of special and patented design, cut and polished from the largest piece of pure calcite crystal which could be obtained.

The light path now had to be switched to a vertical plane using a mirror, so that it could be directed on to a 12in diameter duralumin drum containing 20 small mirrors, each inclined successively at slightly differing angles. This mirror drum revolved at the high speed of 6000rev/min, driven by a two-pole synchronous motor operating from a 100Hz supply. The mirrors had to endure very considerable centrifugal forces and for safety reasons were secured by high tensile steel clamps and screws.

A large translucent screen displayed the colour pictures projected from the mirror drum. Frosted glass would have been too directional for cinema use and the screen consisted of Japanese silk, stretched and doped.



Dominion theartre colour television projector at Baird's private laboratory in Sydenham, 1937. Mid-left is the arc lamp and above it its vent. To the right of the lamp housing, and slightly lower, is the rotating colour filter, lens and fixed mirror assembly. From the fixed mirror, the light shone upwards into the rotating mirror drum above. Photographed by Richard Brice.

Studio equipment

During the mechanical era of television, two main methods of transmission were available. The floodlight system was used by Baird from the earliest days until 1928. The person to be televised stood before a bank of floodlights and a lens focused an image of the scene on to a disc having 30 holes or lenses. A photocell recorded the light variations in the 30 vertical segments.

The spotlight arrangement used between 1929 and 1935 for the first public television service called for the performers to be in a completely dark studio. Through a hole in the wall a mirror drum scanner projected a sharply focused beam of brilliant light which scanned the subjects in sequential vertical strips. Banks of photocells detected the level of reflected light.

For the colour demonstration, Baird had reverted to the floodlight method. Electronic colour cameras had not yet arrived, and in the USA and this country, mechanical devices using rotating colour filters, prevailed.

The colour camera, or scanner, was mounted on a rubber-wheeled truck and quilted material over the casing helped to reduce the mechanical noise. A 20-facet mirror drum, similar to that used in the projector but reduced in size to 8in, rotated at 6000rev/min directing slices of the televised scene to the slotted, colour filter disc.

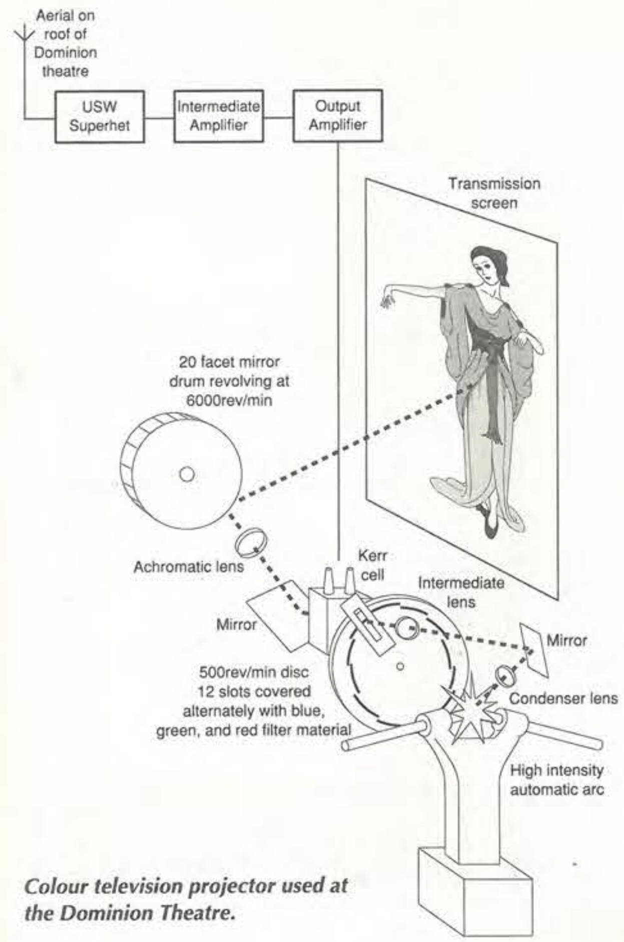
The coloured segments were presented sequentially to a Baird multiplier photocell having a rubidium cathode. This eight-stage multiplier, using the Weiss principle of secondary emission amplification, enabled gains of 10000 to 20000 to be achieved without the twin problems of instability and microphony which were often experienced with thermionic valve amplifiers.

The choice of a rubidium photocell appears to be unusual but the reason could be found in a report of discussions following a paper read by J C Wilson on colour television. Baird, who chaired the meeting, recalled that during his experiments, red and blue fabrics were indistinguishable on the receiver screen and it turned out that the photocells in use were responding equally to the infra-red radiation from these objects instead of the light. Rubidium photocells proved to be relatively insensitive at the infra-red end of the spectrum and this overcame the problem.

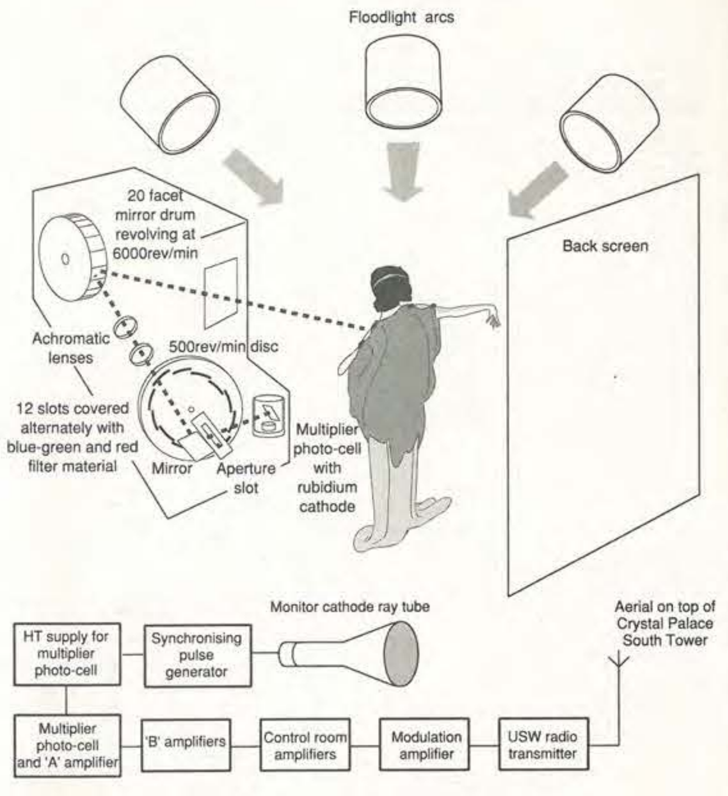
Both the colour camera and projector were manufactured at the works of B J Lynes Ltd, from drawings supplied by Baird's staff.

Results

With a definition of only 120 lines the pictures



Colour television projector used at the Dominion Theatre.



Mechanical colour camera and studio arrangements at the base of the Crystal Palace South Tower.

lacked the clarity of the BBC 405-line service and with a low frame frequency of 8.5 per second, flicker was noticeable. The expected shortcomings of a two-colour system did not materialise and the picture had a perfectly acceptable colour balance.

Daily Telegraph radio correspondent, L Marsland Gander, attended the demonstration with Lord Selsdon, Chairman of the Television Advisory Committee and Dr Clarence Tierney, the Television Society Chairman. He reported "I shared the opinion expressed to me by Dr Tierney that the colours, whatever the deficiencies of definition, were more natural than those of most colour films."

It is remarkable that this important contribution to the progress of colour television resulted from the efforts of a small team of four people working in a converted stable in Sydenham. Baird continued with his colour experiments during the war with an even smaller staff and demonstrated 500-line stereoscopic colour television in 1941. Then followed the first multi-gun colour picture tube in 1944.

I would like to thank Paul Reveley for his help in preparing this account and Richard Vince, another member of Baird's staff, who kindly provided the photographs. ■

Baird's later colour work

Encouraged by what could be achieved using only two colours, John Baird set out to demonstrate high-definition pictures of 600 lines.

Spotlight scanning was used in the studio with rotating colour filters and photocells to detect the level of reflected light. At the receiving end, a projection cathode-ray tube produced a black and white picture, colour being added by another rotating colour filter having equal segments of blue-green and red. With this arrangement a large, bright picture measuring 2 by $2^1/_2$ feet could be obtained.

This unretouched photograph of Paddy Naismith, a visitor to the press demonstration, was taken direct from the screen of Baird's projection colour receiver in December 1940 on Dufaycolor film. It subsequently appeared in the April, 1941 issue of *Electronics and Television.*

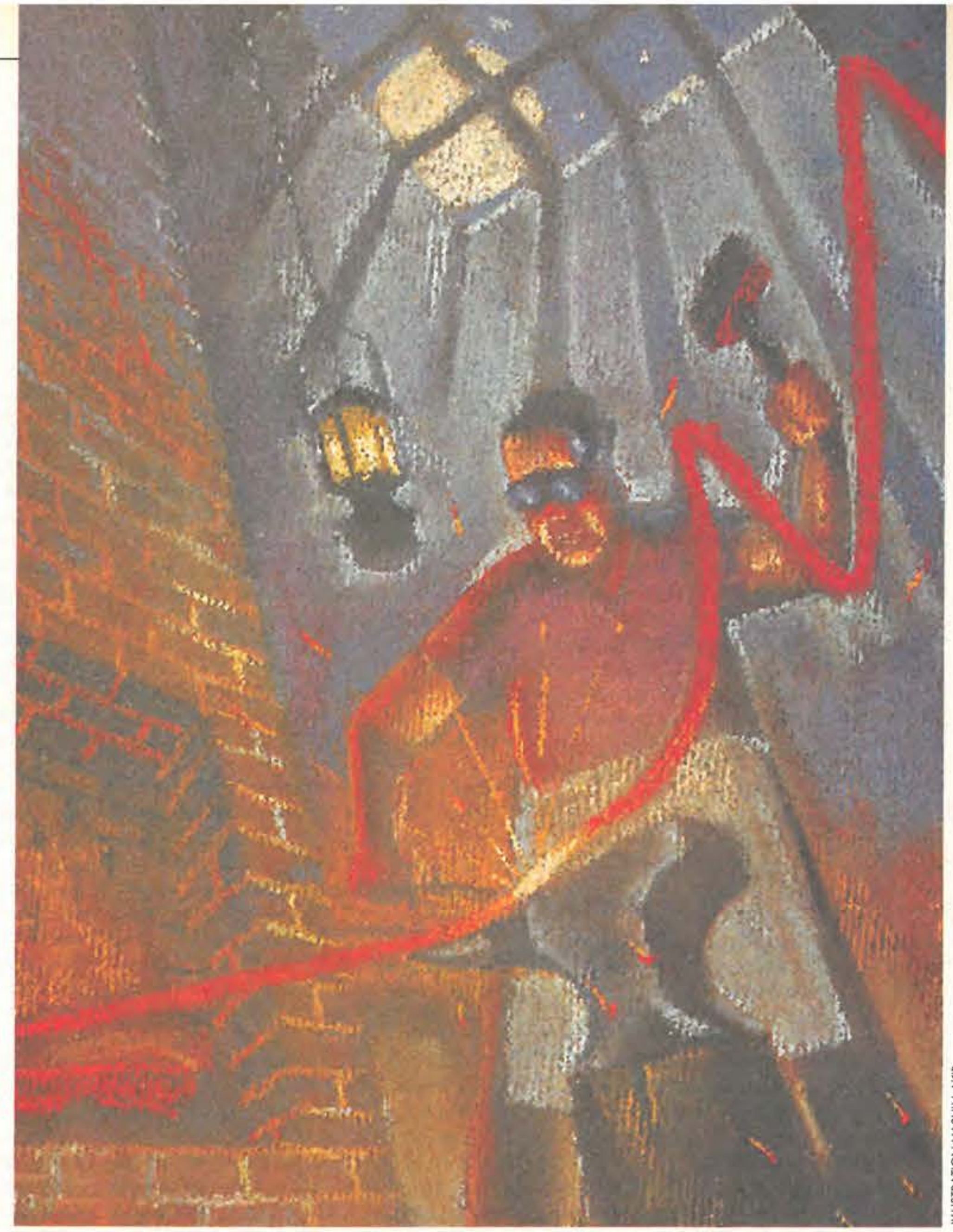


ILLUSTRATION HASHIM AKIB

Ed Cherry looks at distortion in audio power amplifiers and presents a critique of some of the novel attempts to try to reduce it published in recent years.

Ironing out distortion

There is an experiment on audio power amplifiers in the undergraduate teaching laboratory here at Monash University, in which students routinely observe that distortion, output resistance and slewing rate do conform to theoretical predictions. Amplifier design is not a mystery.

This article is a sequel to 'Ironing out distortion' in which I set out some of the basis for predicting amplifier distortions[1]. Between the time I submitted the final manuscript and when it was printed in January 1995, Douglas Self published two more articles on audio power amplifiers[2,3], and since then there have been other contributions from Self[4], Giovanni Stochino[5] and Bengt Olsson[6].

Common-emitter output stages

The common-emitter or common-source output stage is my preferred choice. Self refers[2] to my paper with Dr Greg Cambrell[7] in the *Journal of the Audio Engineering Society*. He gives a good account of some of the pros and cons of common-emitter and common-collector stages in the first part of his article.

Notably, he says that output resistance of a common-emitter amplifier with overall negative feedback is equal to that of a common-collector amplifier with overall feedback. Therefore, loudspeaker damping is the same for both. Self did not mention the principal conclusion of the paper, that intermodulation distortion is less for a common-emitter output stage than common-collector.

In my opinion the relation between common-emitter and common-collector stages could have been explained better. **Figure 1** herewith is Self's Fig. 9 re-drawn as I think it should have been.

Figure **1a)** is the starting point, a basic complementary common-emitter stage in which the collector currents are combined the load. Notice that the bias and drive for the p-n-p and n-p-n sides must be referenced to the positive and negative supply rails respectively, which is awkward but not impossible; I have built amplifiers of precisely this topology[8].

The transistor and its power supply on each side of Fig. 1a are in series around a loop with

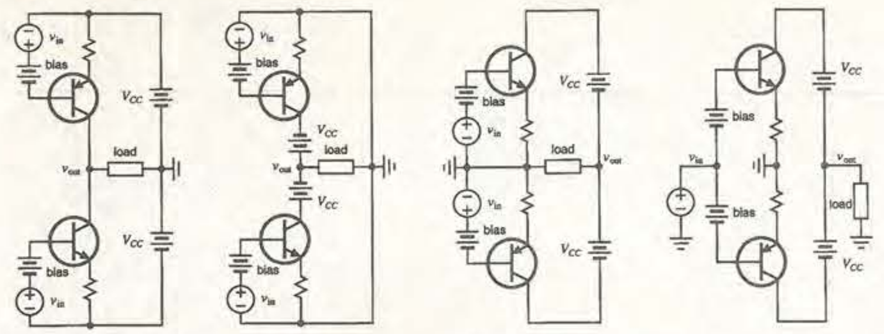


Fig. 1. Evolution of a common-emitter output stage. Figure 1a) is Self's Fig. 9a), a conventional common-emitter stage with the signal input and biasing for each side referenced to the supply rail and with the output collector currents combined in the load. In Fig. 1b) the order of each transistor and its power supply is reversed; these are in series, so operation of the circuit is unchanged. Figure 1c) is a purely cosmetic re-drawing, and Fig. 1d) is a further re-drawing with the input signal generators combined.

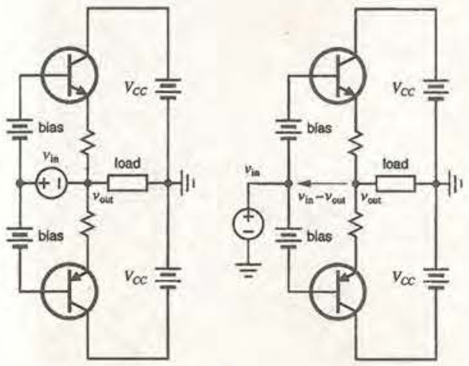


Fig. 2. Evolution of a common-collector stage from common-emitter. Figure 2a) is a true common-emitter stage, derived from Fig. 1d) by simply moving the ground point; the input signal voltage is required to float on top of the output. Figure 2b) is a conventional common-collector stage; the signal voltage between base and emitter in Fig. 2b) is vin – vout, showing that a common-collector stage can be regarded as a common-emitter stage with 100% local voltage feedback.

the load. As Self points out, the order of series components can be altered without changing the operation in any way. Accordingly the supplies are moved as in Fig. **1b)**. And Figure **1c)** is a drastic but purely cosmetic re-drawing – no change whatever to the circuit.

Finally, Fig. **1d)** is a further re-drawing in which the the two input signal generators are combined – again no change to the circuit. Figure 1d) is identical to Fig. 1a).

Figure 1d) is a true common-emitter output stage. The emitters are grounded (neglecting the ballast resistors), the full input signal (plus bias voltage, of course) appears between each base and emitter, and the full output signal (plus quiescent voltage) appears between each collector and emitter.

I believe that this arrangement of a common-emitter output stage was original when published in 1968[9], although it has appeared several times since, in reference 6 for example, without ever really catching on.

Benefits of common emitter

The arrangement of a common-emitter output stage in Fig. 1d) has an enormous practical advantage over any common-collector output stage: *the input signal amplitude is just a few volts peak-to-peak.* Therefore, the only transistors in the complete amplifier which ever need to withstand high voltages are the output transistors. Everything else – including the drivers – can operate from low supplies of, say, ±15V.

A high-voltage transistor must be lightly doped in order to achieve a wide collector depletion layer and reduce the electric field for a given collector voltage. Inevitably this reduces f_T and increases the saturation voltage.

Compared with any common-collector amplifier, much better transistors can be used in all the low-voltage low-level and driver sections of an amplifier based on Fig. 1d). Non-dominant poles can therefore be moved further out, making it easier to stabilise the feedback loop. Higher quiescent and peak currents can be used in order to achieve high slewing rate, without running into either power-dissipation or secondary-breakdown limits.

The only disadvantage of Fig. 1d) is that the main V_{CC} supplies float. Separate supplies are therefore needed for each channel of a stereo amplifier. But then, many highly-regarded amplifiers use separate power supplies anyway.

Figure 2 explains the relationship between common-emitter and common-collector output stages. Figure **2a)** is is identical to Fig. 1d except that the ground point has been moved: the V_{CC} supplies are grounded but now the input signal source must float on top of the output. This is a thoroughly impracticable arrangement, but circuit operation is not changed. The amplifier is still strictly common-emitter: the full input signal voltage appears between base and emitter – neglecting ballast resistors – and the full output signal voltage appears between collector and emitter.

Figure **2b)** shows the conversion from common-emitter to common-collector: the neutral end of the signal source is simply grounded. Now the signal voltage between base and emitter, neglecting ballast resistors, becomes v_{in}–v_{out} rather than v_{in}, which demonstrates that a common-collector stage is nothing more than a common-emitter stage with 100% local voltage feedback. All the output voltage is subtracted from the input voltage to give the drive voltage for the transistors.

Perhaps this gives physical insight as to why the output resistance of a common-emitter amplifier with overall feedback is the same as for a common-collector amplifier. The intrinsic output resistance of a common-emitter stage is high, but this is reduced in **Fig. 3a)** by the overall feedback.

By comparison, the intrinsic output resistance of a common-collector stage is low; this low resistance is attributable to the local feedback, and in Fig. **3b)** it is further reduced by the overall feedback. However, the voltage gain of a common-emitter stage is large whereas the gain of a common-emitter stage is near unity. Therefore the overall loop gain around the common-emitter amplifier is larger than around the common-collector amplifier.

It turns out that the extra overall feedback around the common-emitter stage compensates exactly for its higher intrinsic output resistance. It also turns out – but is much more difficult to prove – that the stability of the feedback loop is the same, higher loop gain not withstanding[7].

Output resistance – a new method

You might be interested in a simple new, general and precise method for finding the input and output resistances of a feedback amplifier[10]. In the same paper is an approximation which appears more reliable than any of the "multiply or divide the resistance-without-feedback by loop gain" types of formula:

- Write down the loop gain. The expression doesn't need to be exact, merely an approximation of the same order of accuracy as the required output resistance.

- Equate this loop gain to unity, and solve for the load resistance. In other words, the output resistance of a feedback amplifier is equal to the load resistance that would reduce the loop gain to unity.

The method is easy, because it requires only the loop gain and not the output resistance without feedback. It works for all feedback amplifiers, not just common-emitter-output or not just common-collector-output, and not just voltage-feedback or current-feedback; you don't need sometimes to multiply by loop gain and sometimes divide.

There is a corresponding method for finding input resistance.

Slewing rate

Self's discussion of slewing rate[3] is correct, but it falls into the category of analysing a bad circuit rather than recommending a good one. Slewing rate is set in amplifiers of the basic common-collector-output topology* by the circuit's ability to charge and discharge the second-stage compensating capacitor, **Fig. 4.**

The charging current flows at both sides of this capacitor, and slewing rate is restricted by whichever side first reaches the available current limit. On the left-hand side of the compensating capacitor the available charging current is near enough to the output from the first stage and, if this stage is a long-tailed pair with current mirror, the positive and negative limiting values are symmetrical and equal to the tail current. On the right-hand side the situation is more complicated: the current available to the capacitor is the left-overs from the algebraic sum of the second-stage collector current, its current-source load current, and the input base currents of the third-stage transistors.

Self noticed that the 'current source' in his amplifier (Tr_6 in Fig. 1 on p. 761 of September 1994 issue) did not supply constant current when its collector voltage was changing rapidly. He observed a 'spike' of current.

Said differently, Self observed that, although his current source might have had a high output resistance, it also has a high shunt capacitance; recall that a capacitor draws a spike of current when the voltage across it changes rapidly. This spike is in the direction which subtracts from the peak current available to the right-hand side of the compensating capacitor. No wonder the slew rate was affected.

If the circuit topology is fixed, obvious reductions in current-source capacitance will accrue from reducing R_B in the C_{source} equation (to zero, ideally) and from increasing R_E.

There are problems with both approaches in Self's amplifier, where the first and second stage current sources share a common voltage reference. Reducing R_B provides a kind of feedback which decreases/increases the first-stage tail current on fast positive/negative swings. Increasing R_E reduces the peak positive output voltage from the complete amplifier, hence reduces available power output.

Better by far to change the circuit topology. In my original article I showed (Fig. 5 of Ref. 1} a really solid first-stage tail-current source using a 10V zener diode. I didn't comment on Self's second-stage current source, but in fact I always use a bootstrapped resistor as described, for example, in Ref. 11 – an arrangement which Self largely dismissed.

A resistor bootstrapped as in **Fig. 6** eliminates the problem of capacitive loading, it actually increases the peak positive output voltage available from the amplifier, and it is cheap. The sum of (R_1+R_2) should be chosen to provide the desired quiescent current in the second stage,

$$I_{2(quiescent)} \approx \frac{V_{CC}}{R_1 + R_2}$$

The ratio of R_1 to R_2 is not critical, except that R_1 should be as large as possible consistent with $R_2 >> R_L$.

Time constant R_2C_B should be chosen having regard to the lower 3dB cut-off frequency of the amplifier: $\omega_{low}=R_2C_B>>1$.

Shifted compensating capacitor

If you want to change the circuit, then shifting the compensating capacitor as shown grey in Fig. 6 has many advantages; I have described it[11] as "...the greatest bargain of all time...". It is very effective in reducing cross-over distortion – the major residual distortion in Self's 'blameless' amplifier. It also helps with slew symmetry, because the loading effect of the capacitor is transferred from the second-stage collector, where the available current is milliamperes, to the output, where the current is amperes.

Until now there has been no reaction from readers to this recommendation in my article, but I have in the past been told that shifting the compensating capacitor provokes high-frequency oscillation. This is not my experience: I have built dozens of amplifiers, and I have published an analysis[12] which has never been challenged.

All this prompts the question "Is the supposed oscillation for real?" Is it perhaps that believers in the oscillation are merely reporting what someone else has told them? I would

Current source analyses

Figure 5a) is an n-p-n current source, the "flip" of Self's p-n-p circuit. Note the collector-base capacitance C_{CB} of the transistor. In the vacuum-tube era a circuit of this topology was known as a 'reactance-tube modulator'. Its function was to provide a voltage-variable capacitor to modulate the frequency of an *LC* oscillator. The capacitance looking into the anode of Fig. **5b** is,

$$C_{modulator}=g_m R_G C_{AG}$$

The similarity of Figs 6a) and 6b) is apparent, and the capacitance looking into the current source is,

$$C_{source} = \left(\frac{R_B}{R_E}\right) C_{CB}$$

Figure **5c** is Self's *p-n-p* current source with actual component values marked; the capacitance looking into the collector is about 100pF – equal to his compensating capacitor. No wonder the slew rate was affected.

*Fig. 1a) on p. 632 of August 1993 issue, or my Fig. 1 on p. 15 of January 1995.

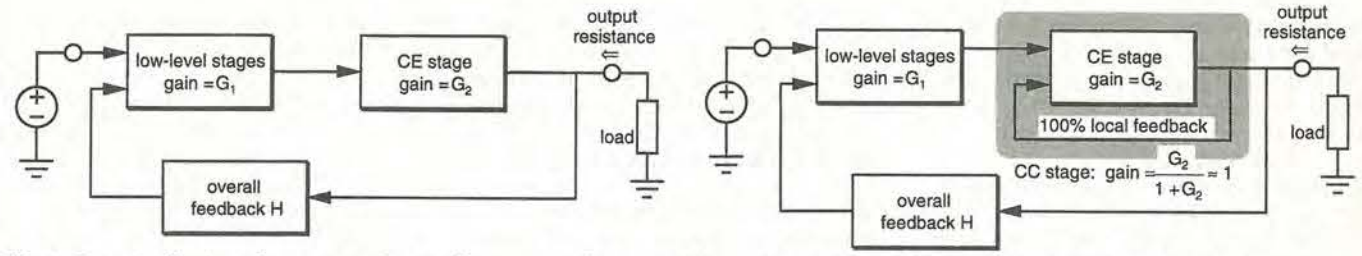


Fig. 3. Output resistance of common-emitter and common-collector amplifiers. The total feedback around the output stage is the same, and therefore the output resistances are equal.

Benefits of IGBTs in power driving

I would like to place it on record that a complementary common-emitter or common-source amplifier with floating power supplies as in Fig. 1d provides an elegant solution to driving the gates of large insulated-gate bipolar transistors, or igbts, in high-power pulse-width modulated drives and inverters. In this application the gate must be driven between about +15V and –10V in a few nanoseconds; transient current in the gate capacitance during switching amounts to several amperes.

Figure A shows the arrangement. Parasitic gate-lead inductance has little influence on switching speed, because it is in series with the driver mosfet drains which behave like current sources.

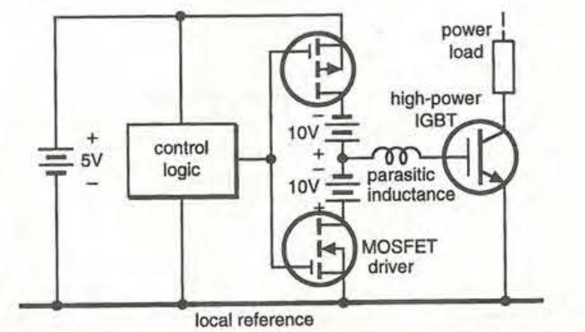


Fig. A. Complementary common-source enhancement-mode mosfet amplifier based on Fig. 1d, for driving an igbt gate between +15V and –10V in a few nanoseconds.

be interested to hear from anyone with first-hand experience of the problem. However, before making contact with me, please read what I said on pp. 19-20 of *Electronics World* for January 1995:

- I can believe in local parasitic oscillation of the first member of the output-stage Darlington – the 'drivers' – as distinct from oscillation of the main feedback loop. Driver transistors such as *BD139/140* with f_T around 100MHz usually oscillate when biased to 5-10mA at the end of 10-20cm leads. Check the frequency of the oscillation: is it near the unity-loop-gain frequency, or is it significantly higher? For a common-collector-output amplifier with the low-level stages shown in Fig. 4,

$$\omega_{\text{unity loop gain}} = \left(\frac{1}{R_{E1}C}\right)\times\left(\frac{R_{F1}}{R_{F1}+R_{F2}}\right)$$

- My amplifiers always feature impeccable layout and bypassing with separate quiet and noisy ground tracks, and short leads to the drivers. All of this discourages parasitics.
- For the same reason I routinely provide 'stopper' capacitors of 30–50pF between collector and base of the drivers, using the shortest possible leads – no more than 1cm.
- My amplifiers always incorporate a correctly-designed load-stabilising network.
- My amplifiers always include judicious emitter degeneration in the second stage as shown in Fig. 6.
- In common-collector amplifiers – as distinct from my preferred common-emitter – I use a bootstrapped resistor as the second-stage current source.

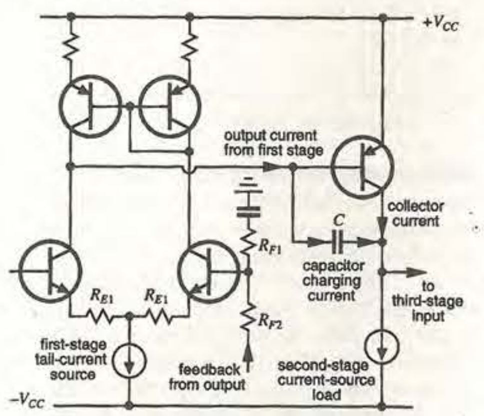


Fig. 4. Low-level stages of a common-collector-output amplifier. Note that the polarity is flipped relative to Self's articles, but the same as in Ref. 1.

If any reader has taken care of all these matters and still experienced oscillation when the lag-compensating capacitor is shifted, I would be pleased to make contact. But I do urge you to try shifting the capacitor. It effects a remarkable reduction in cross-over distortion.

Load-stabilising Zobel networks

Load-stabilising networks are used to ensure that the amplifier proper is presented with something like its nominal load resistance at high frequencies. This is the case even if the external loudspeaker load is highly reactive. Secondly, they are used to prevent rf interference, picked up by the loudspeaker leads acting as antennae, from finding its way back into the first stage via the feedback network.

Since submitting the final manuscript of Ref. 1, I have realised that there are in fact two families of load-stabilising network – not just the two networks which Thiele proposed[13]. **Figure** 7 shows the general models. For both circuits the inductance and capacitance should satisfy,

$$\frac{L}{R_O} = R_O C = \frac{1}{\omega_x}$$

where R_0 is the nominal loudspeaker load resistance, probably 8Ω, and ω_X is the network cut-off frequency. In addition, for **Figs. 7a** and **7b** respectively,

$$R_2 = \frac{R_O^2}{R_1 - R_O} \qquad \text{(a)}$$

$$R_2 = \frac{R_O^2}{R_1 + R_O} \qquad \text{(b)}$$

Note the sign change in the denominator.

In Fig. 7a), if R_1 is chosen as infinity, i.e. the capacitor branch is open-circuited, then from equation (a) above R_2 needs to equal 0 – short-circuit the inductor in other words. As a result, the whole network disappears. This corresponds to the limiting case of an amplifier without a load-stabilising network.

On the other hand if R_1 is chosen as its minimum allowed value of R_0, then R_2 is infinity and Fig. 7a) reduces to Thiele's original (Fig. 9a of Ref. 1). Between these extremes is a continuum of allowed resistance values. Is any especially desirable?

Thiele's original with R_2=∞ gives the greatest isolation between amplifier and load, and the greatest attenuation of rf interference. But the circuit does ring badly if the external load is made pure capacitance.

Whether a pure capacitive load is realistic of anything practical is a moot point, and in any

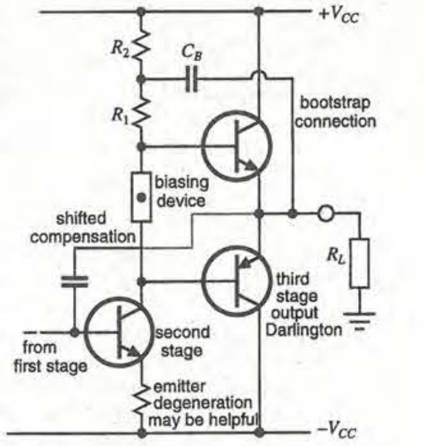


Fig. 6. Bootstrapped resistor as second-stage current source. Shifting the compensating capacitor (shown grey) reduces crossover distortion and can improve slew symmetry. Second-stage emitter degeneration helps with stability.

case the ringing is a simply a resonance between the inductor and this capacitance – not an indication of approaching instability in the amplifier.

If anyone is worried by the ringing, however, then damping can be increased by using some finite R_2 and the corresponding R_1. The price, of course, is reduced isolation and reduced rf attenuation. Thiele's original (or my modification of it in Ref. 1) is still my preferred choice.

Similarly, if in Fig. 7b you choose R_1=∞ and R_2=0, the whole network disappears. If you choose R_1=0 and R_2=R_0 on the other hand, the circuit reduces to Thiele's original. Again there is a continuum of allowed resistance values between these extremes.

Notice that this form of Thiele's network (Fig. 9b of Ref. 1 – the circuit I described as crazy-looking with 100nF directly across the loudspeaker) is much better in regard to ringing than the more common **Fig. 8a**. I urge you to try **Fig. 8b** – crazy-looking or not.

Distortion off the supply rails

Self's cascode-like first stage[4] is an ingenious solution to the problem of distortion on the supply rails re-entering the circuit via the lag-compensating capacitor. Congratulations. However there are at least two other solutions.

My preferred choice is the common-emitter output stage as described above. Here there is no significant signal on the low-voltage supplies to the low-level stages, hence no problem.

Alternatively, with a common-collector output stage use nested differentiating feedback loops as in Ref. 11. Here the return end of each lag-compensating capacitor is connected to a virtual ground. Again there is no problem.

First-stage c-m distortion

Related to distortion off the supply rails is distortion which enters via the finite common-mode rejection of the first stage. Signals on

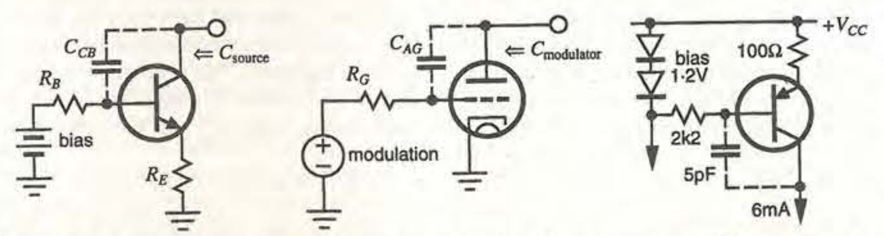


Fig. 5. (a) n-p-n current source; (b) reactance-tube modulator, a voltage-variable capacitor from the vacuum-tube era; (c) Self's p-n-p current source.

the supply rail appear more-or-less unattenuated at the collectors of the first stage unless something like Self's cascode is included, and harmonics of signal on the supply rails can introduce distortion via this mechanism.

However there is another common-mode distortion mechanism. The input and feedback signals, applied to the bases of the input long-tailed pair, can be resolved into differential and common-mode components.

The principal component of current output from the first stage is proportional to the small difference between the input and feedback voltages; half this difference appears between the base of each transistor and the top of the tail. Simultaneously the average of the input and feedback voltages appears between each collector and the top of the tail as a large common-mode signal.

The differential and common-mode signals will intermodulate and produce beat frequencies if there is any dependence of first-stage differential gain on collector voltage.

In practice there is such a dependence, and the gain variation is something like linear with collector-emitter voltage. It follows that the intermodulation is proportional to the product of the differential and common-mode signal amplitudes, and its frequency is twice the input signal frequency.

In other words, the intermodulation distortion appears like second-harmonic distortion, although it truly is the result of intermodulation – perhaps auto-intermodulation would be the correct description. Adding a cascode, to hold the collector voltage constant, will not help; it is the large signal voltage at the emitter that matters.

A number of physical mechanisms are involved for bipolar-junction transistors, all associated with widening of the collector depletion layer as collector-emitter voltage increases:

- Classical text-book Early effect, by which base-emitter voltage for a specified collector current depends on collector-emitter voltage;
- Modulation of transistor base width, hence β and base current, and ultimately modulation of the signal voltage drops across any series resistance in the base circuit – the source resistance, the Thévenin equivalent resistance of the feedback network, and transistor base-spreading resistance;
- 'pinching' of the base resistance itself, hence modulation of the voltage drop associated with base current.

Field-effect transistors exhibit a corresponding dependence of differential gain on drain voltage. They too can generate second-harmonic-like distortion via auto-intermodulation. Common-mode distortion mechanisms are not confined to bjt stages nor to modulation of base current.

Simulations may not reveal common-mode distortion. Most Spice transistor models treat the Early voltage as a constant where in fact it varies as something like the square root of collector-emitter voltage. Also, simulations are

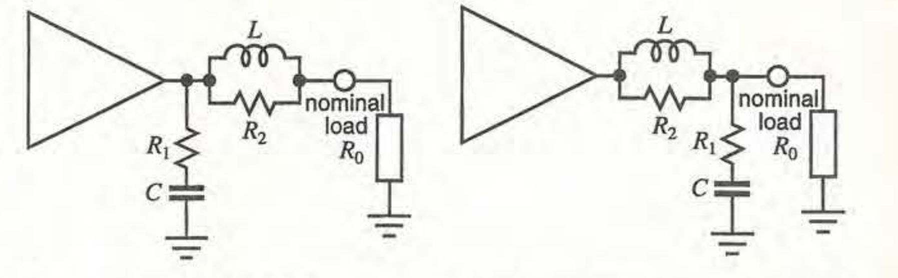


Fig. 7. Generalised load-stabilising networks. These reduce to Thiele's networks for special cases of the resistor values.

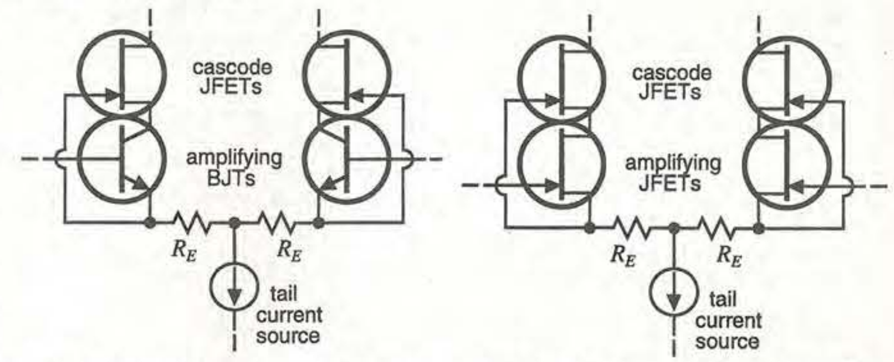


Fig. 8. Bootstrapped cascode long-tailed pairs, using a JFET as the top member. The top JFET needs appropriate values for V_P and I_{DO} (I_{DSS}) in order to provide headroom for the bottom device.

likely to represent both transistors of a long-tailed pair as identical – apart, perhaps, from quiescent conditions – whereas in a real amplifier they are not identical and the unbalance is significant. Second harmonic cancels in a perfectly-balanced circuit.

Because the intermodulation is proportional to the product of the differential and common-mode signal voltages, distortion from this cause can be reduced by reducing either voltage. The differential voltage can be reduced by increasing the feedback loop gain at the signal frequency, but this means increasing the overall closed-loop cut-off frequency and hence increasing the likelihood of instability.

Increasing the overall closed-loop gain reduces the common-mode component at all frequencies and hence reduces the input voltage required for full output; this is one of the reasons why I prefer the 300mV typical of old-style vacuum-tube amplifiers, to today's more usual 0·7-1·0V.

If a hardware solution is required, I use the bootstrapped cascode arrangements shown in Fig. 8.

Power mosfets versus bipolar devices

I agree with everything Self says about the relative nonlinearity of bjts and mosfets in output stages. However he has omitted one important consideration: gain-bandwidth product. I also feel he has over-stressed the importance of crossover distortion when there is the simple fix of shifting the lag-compensating capacitor as in Fig. 6.

Fifty years ago Bode showed[14] that the amount of feedback which can be applied to an amplifier, and hence the amount by which distortion can be reduced with specified margins against instability, is proportional to active-device gain-bandwidth product *GB* exponentiated to a power that depends on the phase margin. Here gain-bandwidth product is used in Bode's precise sense, related ultimately to the transit time of carriers through the control region.

It follows that bjts are the preferred devices for the low-level stages of a feedback amplifier. Typical types, such as *BC547s*, have transit times around 500ps and hence *GB* of 300 to 500MHz, compared with 1ns and 100-200MHz for silicon j-fets such as the *2N5485*.

However, the corresponding numbers for power bjts like the *MJ802* are around 100ns and 1 to 2MHz, compared with 1ns and something over 100MHz for power mosfets such as the *IRF240*. More feedback can in theory be applied around power mosfets.

In the terminology of Refs 1 and 11, output-stage distortion for mosfets is almost entirely a consequence of nonlinearity in g_{m3}; crossover distortion for both bjts and mosfets is also a consequence of nonlinearity in g_{m3}.

Figure 4 of Ref. 1 shows that sensitivity towards changes in g_{m3} is inversely proportional to the second-stage lag compensating capacitor. Therefore distortion is inversely proportional to this capacitor.

Comparison anomalies

In August 1995 John Linsley-Hood's published a comparison between bjts and mosfets[15]. In this comparison, the compensating capacitor C_{13} in his Fig. 1 is marked 'value depends on circuit'. In other words, the comparison of bjts, mosfets and igbts was not made on a level playing field.

The fact that measured distortion for the mosfets was about half that for the bjts is of itself meaningless; we must also be told the ratio of the compensating capacitors in the two experiments.

My guess is that the compensating capacitor was smaller in the case of the mosfets as compared with the bjts. As explained above, Bode's work shows that much more feedback can be applied to mosfets at high frequencies without approaching instability, because their transit time is shorter; mosfets require less compensation than bjts.

If the mosfet compensating capacitor was half the bjt capacitor, then Linsley-Hood's experiment shows that the open-loop distortions of mosfets and bjts are about the same. If the mosfet capacitor was smaller than half the bjt capacitor, then the open-loop bjts are better than the mosfets – as Self claims.

In the end, however, it is closed-loop distortion that matters, not open-loop, and Linsley-Hood's experiment confirms my preference for mosfets. Their open-loop distortion may be somewhat greater than for bjts, but more feedback can applied around them.

To repeat the quotation from Ref. 8: "The author's approach to designing a high-quality amplifier is to choose a simple topology based on common-emitter amplifying stages and apply negative feedback to reduce distortion. 'Clever' circuit topologies (other than push-pull operation) rarely give better than a ten-fold reduction in distortion on a production basis. Feedback, however, can reduce distortion almost indefinitely." ■

References

1. Cherry, E. M., 'Ironing out distortion', *EW&WW*, vol. 101, pp. 14–20, January 1995.
2. Self, D., 'Common-emitter power amplifiers', *EW&WW*, vol. 100, pp. 548–553, July 1994.
3. Self, D., 'High-speed power', *EW&WW*, vol. 100, pp. 760–764, September 1994.
4. Self, D., 'Distortion off the rails', *EW&WW*, vol. 101, pp. 201–206, March 1995.
5. Stochino, G., 'Audio design leaps forward', *EW&WW*, vol. 100. pp. 818–824, October 1994.
6. Olsson, B.G., 'Better audio from non-complements', *EW&WW*, vol. 100, pp. 988–992, December 1994.
7. Cherry, E.M. and Cambrell, G.K., 'Output resistance and intermodulation distortion of feedback amplifiers,' *J. Audio Eng. Society*, vol. 30, pp. 178–191, April 1982.
8. Cherry, E.M. 'A high-quality audio power amplifier', *Proc. IREE Australia*, vol. 39, pp. 1–8, Jan/Feb. 1978.
9. Cherry, E.M. and Hooper, D.E., *Amplifying Devices and Low-Pass Amplifier Design*, Wiley, New York, 1968. See Fig. 14.26b on p. 891.
10. Cherry, E.M. 'Input impedance and output impedance of feedback amplifiers', *Proc. Inst. Elec. Engrs. – Circuits, Devices & Syst.*, vol. 143, pp. 195–201, April 1996.
11. Cherry, E.M. 'Nested differentiating feedback loops in simple audio power amplifiers', *J. Audio Eng. Society*, vol. 30, pp. 295–305, May 1982.
12. Cherry, E.M. 'Feedback, sensitivity and stability of audio power amplifiers', *J. Audio Eng. Society*, vol. 30, pp. 282–294, May 1982. Also *ibid*, vol 31, pp. 854–857, November 1983.
13. Thiele, A.N., 'Load stabilising network for audio amplifiers', *Proc. IREE Australia*, vol. 36, pp.297–300, September 1975.
14. Bode, H.W., *Network Analysis and Feedback Amplifier Design*, van Nostrand, Princeton NJ, 1945.
15. Linsley-Hood, J., 'Expert witness', *EW&WW*, vol. 101, pp. 684–685, August 1995.

Make your own fluxmeter

You can't see or feel them but a body of opinion says that they can harm you. Frank Ogden describes an instrument to measure low frequency flux fields

We haven't heard so much lately about low frequency magnetic fields from power lines and mains equipment and their alleged connection with health risks. I hold a personal view that the various Government inspired studies, none of which indicate significant linkage between disease and exposure, have not looked for chronic, measured exposure. They searched for correlation between disease and magnetic AC field in likely locations: they did not survey retrospectively location addresses of actual illness.

Most researchers suggesting disease linkage suspect sustained medium level exposure in the range 300 to 1000nT as being significant. Short, intense bursts such as those received when operating a hair dryer or other electrical equipment are not considered important. In short, LF radiation is probably of no concern unless you live or work under - or above - a power line, or within the stray field of a piece of electrical equipment in continuous operation.

The single-coil handheld design given in this article was based on an idea put forward by Alasdair Phillips and published in Electronics World back in April, 1992. This update allows an instant LF field survey which, at the very least, may be used to determine whether a more detailed survey is desirable.

While overhead National Grid power lines predictably exhibit AC flux peaking in the region 500 to 800nT, similar - indeed higher - levels frequently occur over a much smaller corridor along town streets corresponding to buried power lines. Aside from alleged health risks, the instrument provides a fascinating readout as it lays bare the high power circuits buried under our streets.

It also reveals hotspots around the home: ring main wiring may create fields reaching levels of 600nT within a few inches of their routing; the scanning coils fitted in domestic TV drive the instrument off the clock within a couple of feet of the set and significant field generation may extend at typical viewing distance.

The simple instrument described here will deliver an AC flux measurement accuracy within 10% without any form of calibration. This requires the 215-turn sensor coil to be wound accurately, that it should intercept about 78sq cm of flux, and that the instrument housing does not distort the incident flux.

Such a coil will deliver 0.5 microvolt EMF at 50Hz for each nanoTesla of incident flux. Thus, when coupled to an amplifier with a gain of 2000, a 1000nT 50Hz sinewave flux will generate 1V rms at the amplifier output. This can be measured with a calibrated precision rectifier, DMM or other measuring instrument connected to the output terminals.

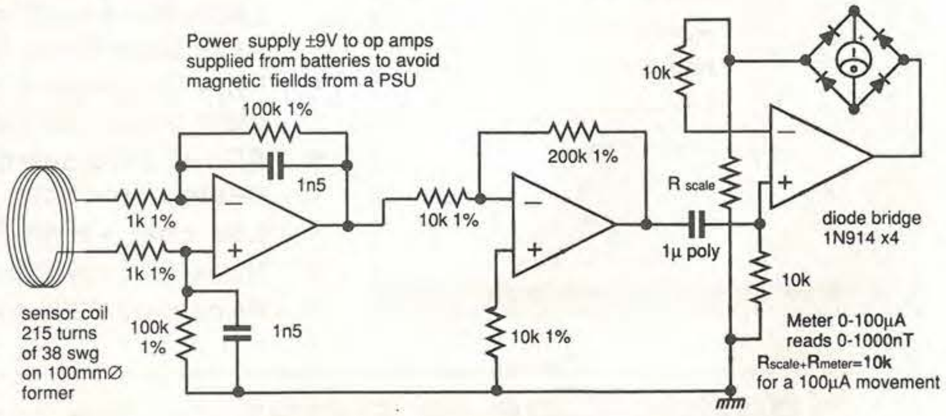
The circuit is almost too simple to warrant description. The sensor coil couples directly to a two-stage differential amplifier with a gain of 2000. Thus, when used with the coil as specified, an input 50Hz, 1mT flux generates one volt rms output at the coupling capacitor to the precision rectifier. The rectifier/meter circuit is pre-calibrated against a decent voltmeter or known voltage source.

Alasdair's orginal piece, which advocated a single-ended amplifier block, had all sorts of caveats about shielding the coil, wires and other things. The differential configuration gets rid of all that. The pair of capacitors on the front end ensures that the sensor coil doesn't pick up RF, or allow HF oscillatory feedback from the high level signal downstream of the amplifier blocks. The arrangement given here is unconditionally stable even when mounted in a small plastic box and requires no screening. As mentioned earlier, placing signifcant pieces of metal within the capture aperture of the loop will affect the accuracy of the resultant readings.

The op-amps can be any mildly superior devices. Key parameters are low 1/f noise, low DC offset and full stability at unity gain.

Sensor coil

This comprises 215 turns of fine (36 to 40 swg) enammelled copper wire pile wound onto a 100mm diameter non-conducting former to form a "ring" winding. I used a glass jar of the right diameter as a winding mandrel. The finished coil was removed from the jar and wound toroidally with insulating tape to form a stable structure. The winding is terminated onto flexible multistrand leadout wire taped into place on the coil. The leadout then collects to the amplifier. ■



The 215-turn 100mm diameter sensor coil generates 0.5μV rms for every nanoTesla of 50Hz flux which it intercepts. The differential op-amp pair have a combined gain of 2000. Thus 1000nT flux produces 1V rms at the output to the precision rectifier

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049

CIRCUIT IDEAS

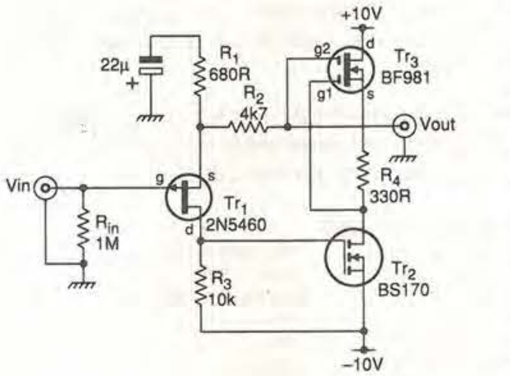
Simple fet audio preamplifier

Although there have been many discrete fet designs for good quality audio preamplifiers, there has been a tendency towards elaboration and hard-to-find components, leading to expensive designs. This one, while being almost skeletal in comparison, gives smooth, clean sound, with very low distortion, and is suitable for line-level application. Fets used are not specifically audio types; I chose them for their availability.

Voltage gain is $1+R_2/R_1$, which with the values used gives 18dB; measured –3dB attenuation was at 1.5MHz, giving 12MHz gain/bandwidth product. Slew rate is 10V/µs, output impedance around 50Ω and, with a ±10V power supply and driving a 10kΩ load, output voltage before clipping is 5.7Vrms.

I have no access to distortion measuring equipment and used a spectrum analyser to compare input and output. Input came from an oscillator wiuth second and third harmonics at –70dB and –75db respectively compared with the fundamental. Output, at 1Vrms, showed an identical spectrum, which indicates that the thd of the circuit was well below that of the test signal, even up to 20kHz, where many bipolar op-amps start to distort.

Phil Regalia
Nanteau-sur-Lunain
France



Considerably simpler than many fet preamplifiers, this one gives a smooth sound, particularly at higher frequencies, where some bipolar transistor preamplifiers have a tendency to sound harsher and more "aggressive".

Smps inrush tester

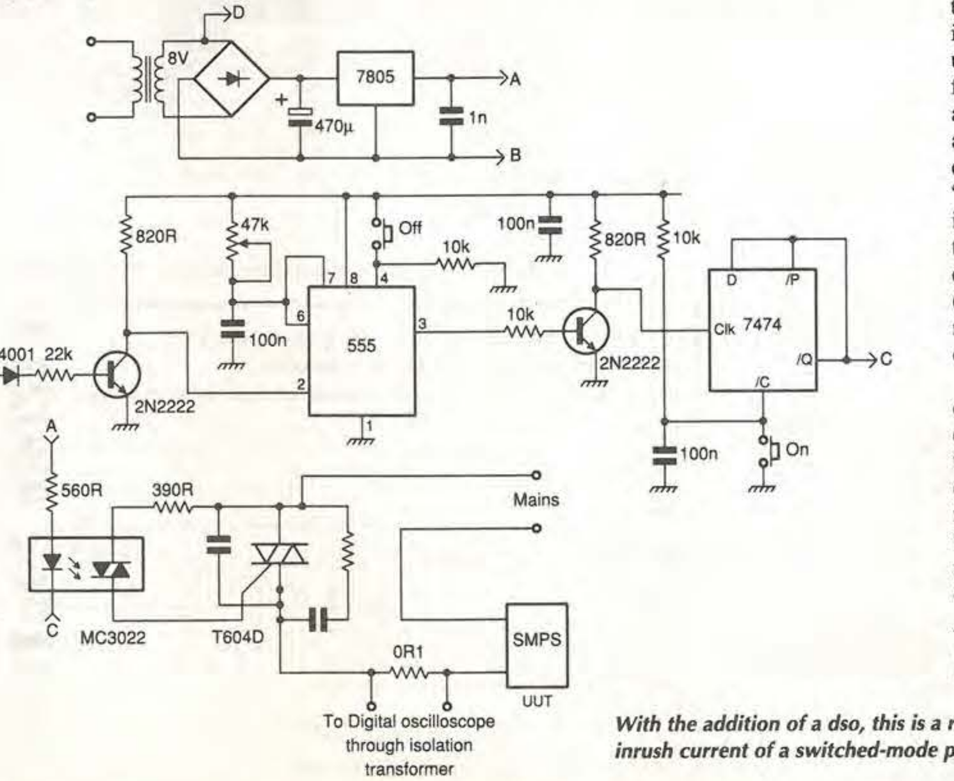
£100 WINNER

Inrush current, that taken by a switched-mode power supply at switch-on, the reservoir capacitors being uncharged, is large and short-term. It is necessary to examine this characteristic on a new design and this circuit provides the means.

Inrush is maximum when switch-on occurs at the peak of the mains waveform. Taken from the mains transformer secondary, this waveform is shaped by the *2N2222* in (b) and used to trigger a *555* monostable flip-flop, the output of which being adjusted so that its falling edge appears at the ac peak and acts as clock for the *7474* flip-flop. When the "ON" switch is made, the smps in (c) is turned on by the opto-isolated triac, voltage corresponding to inrush current appearing across the 0.1Ω (non-inductive) shunt, where it is measured using a digital storage oscilloscope.

Bear in mind that inrush current also depends to some extent on the source characteristic, cable length and thickness and the number of connections. It is, perhaps, a good idea to keep them the same for all tests. Allow enough time between measurements for the reservoir capacitors to discharge.

Jayant Kathe
Bombay
India



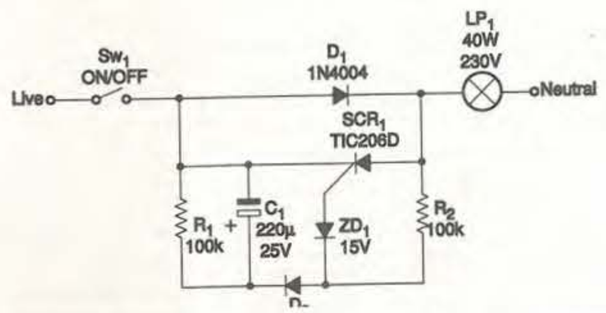
With the addition of a dso, this is a repeatable method of measuring the inrush current of a switched-mode power supply.

Soft-starting bedside lamps

Turning on a bedside lamp at 3o'clock in the morning is not often a pleasant experience, depending on what one was doing the night before. This circuit switches the lamp on at reduced power and brings it on fully after a few seconds. It also makes lamps last a very long time.

At the instant the switch is closed, there is no voltage on C_1 and the *TIC206* triac is not conducting (the triac is cheaper than a thyristor and has the same function here). Diode D_1 half-wave rectifies the live line and, during the half cycles when D_1 is not conducting, C_1 charges through R_2 and D_2. When this voltage gets to about 15V, the zener begins to conduct and carry current to the gate of the triac, which conducts; in this condition, the voltage across C_1 does not exceed its rating. On switch-off, C_1 discharges through R_1.

H A Burnham
Wye
Kent



For sensitive souls who find switching on a lamp in the middle of the night as much of a shock as being tipped out of bed, this driver brings the lamp on gently, coming to full brightness in about four seconds.

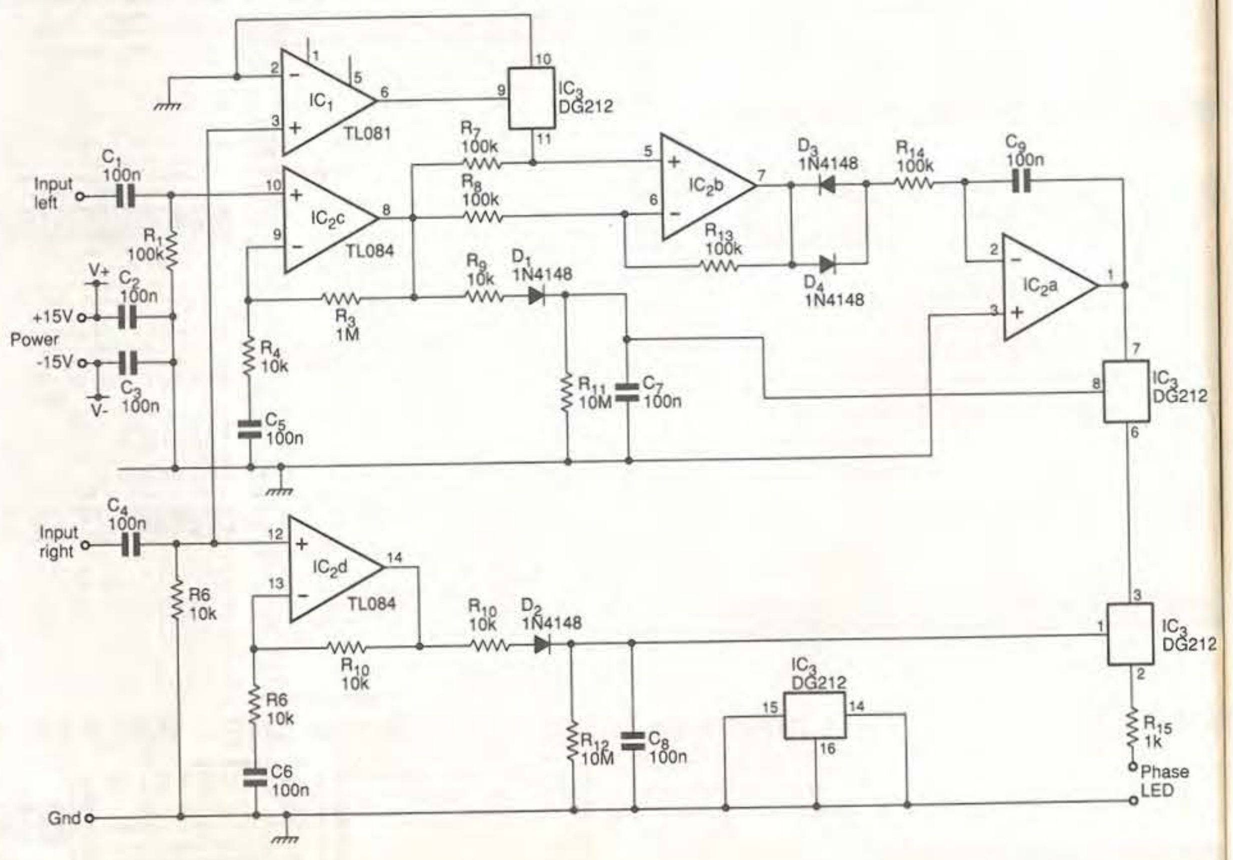
Audio phase indicator

A bi-colour led glows green for L and R in-phase stereo signals, red for out of phase and remains off when no signal is present.

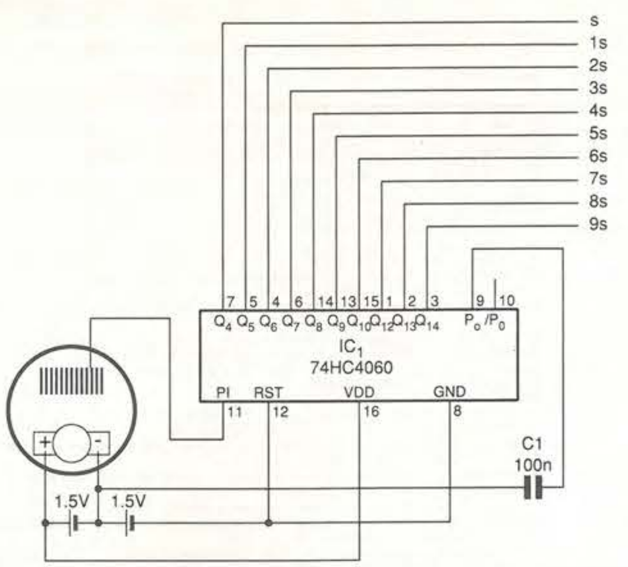
Left input signal is amplified and clipped, the pin 6 output driving the synchronous rectifier at pins 5,6. Right-channel signal is squared by the comparator IC_1 whose output controls the analogue switch IC_3, pin 9, to switch the rectifier in and out of phase, its output therefore following the relative phase of the two signals and being integrated at IC_2 pin 1. This output is positive or negative with respect to ground, depending on whether the inputs are in or out of phase. The integrator samples and holds for no signal at $D_{3,4}$ to minimise detection of incorrect phase information.

If there is no signal or only one signal present, there is no input to one or both of the analogue switches at IC_3 pins 1 and 8 and the led stays off. Otherwise, the led responds to a negative or positive integrator output.

Mike Law
BCD Audio Windsor
Berkshire



To show the relative phase of pair of stereo inputs, this circuit makes a led glow green or red, or stay unlit for no signal.

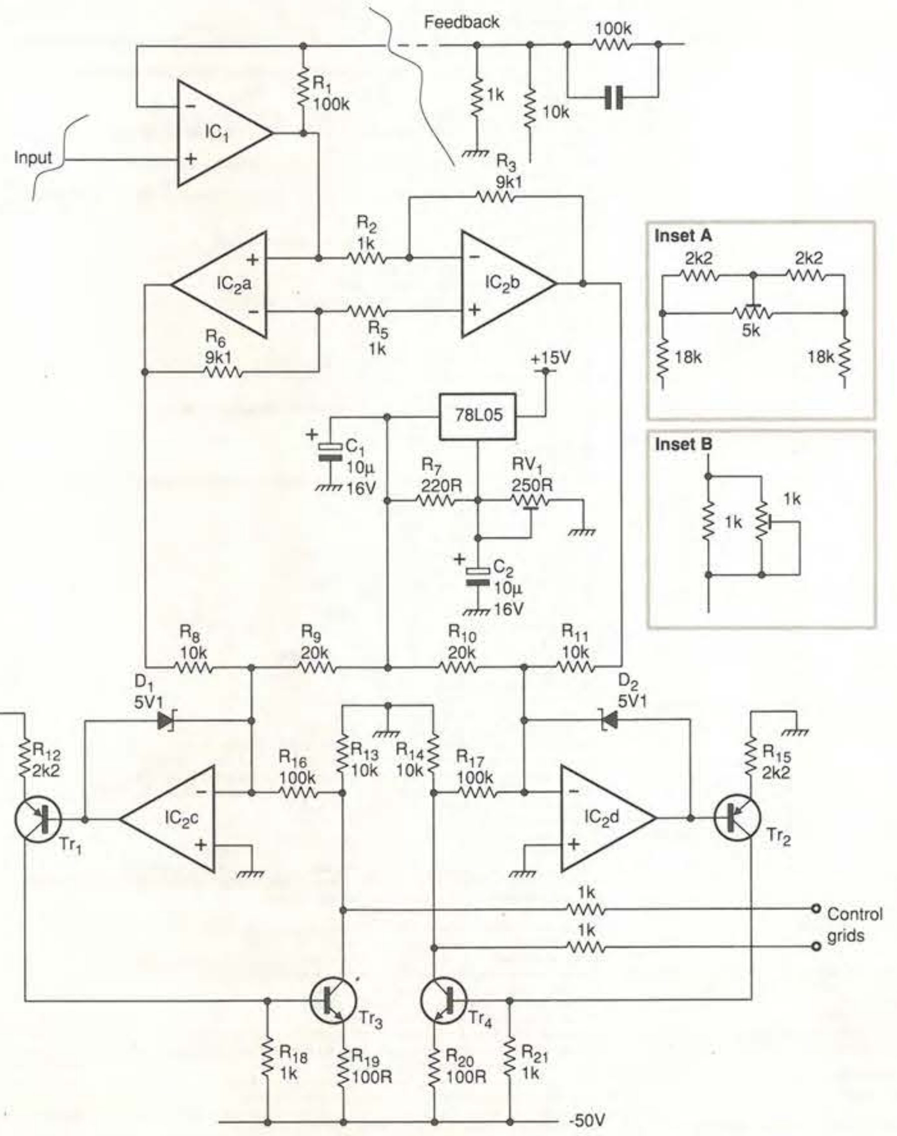


Watch clockmaker

A popular digital watch has thirteen lines to the lcd. On any but the rightmost and leftmost, you will find a 32Hz square wave of 3V balanced about zero id the reference point is the watch's battery negative. If you use any of them to drive a *CD4020* 14-bit binary counter, the counter outputs will provide very precise 0.5s to 512s clock signals.

Yongping Xia
Torrence
California
USA

Divide one of the lcd outputs from a five-finction digital watch to get any clock signal with a period between half a second and 512 seconds.



Integrated-circuit replacement for transistors in de Jager's hybrid amplifier.

IC_1 TL071 or TL072 (Spare amp may be used to replace 741 in original design)
IC_2 TL074
Tr_1, Tr_2 BC640
Tr_3, Tr_4 BC639
R_1 to R_6, R_8 toR_{11}, R_{16}, R_{17}, should preferably be 1% tolerance

Ic phase-splitter for valve audio output

In *Electronics World* for November, 1996, Wim de Jager described a hybrid transistor/valve audio amplifier[1]; this circuit replaces the transistors with integrated circuits.

Phase-splitter $A_{2a,b}$ produces gains of 10.1 and –10.1 and feeds the driver stages A_{2c}, $Tr_{1,3}$ and A_{2d}, $Tr_{2,4}$. Level shifting is provided by the *78L05* regulator and R_7, Rv_1, which produce an adjustable reference of 5-10V to drive an offset current through $R_{9,10}$, shifting the output level to –25V to –50V. Diodes $D_{1,2}$ avoid the op-amps becoming saturated.

Since the phase-splitter gain is around 100, the error amplifier A_1 needs only unity gain, R_1 providing this to avoid over-correction.

To fine-tune matching/load-sharing in the valve output stage, replace $R_{9,10}$ with circuit A, which will correct balance at zero load. For full-load trim, insert circuit B in series with $R_{8,11}$. Settings of these two adjustments are slightly interactive. To increase the error and therefore assist in adjustment, temporarily short R_1.

Sujit Liddle
New Delhi
India

Reference

1. de Jager, W., 'Hybrid power amplifier' *EW+WW*, November 1996, p. 897.

Reducing voltage reference noise

Conventional voltage reference circuits, which take the form of a low-pass *RC* circuit followed by a buffer, as in **Fig. 1**, have their disadvantages: dc errors come from leakage through the capacitor and noise generated in the buffer is added to that from the reference.

To reduce the effect of capacitor leakage to an insignificant level, the *RC* low-pass circuit goes after the buffer, but within its feedback loop, as shown in **Fig. 2**, so that errors caused by the leakage are reduced by the buffer loop gain; leakage errors caused by C_1 are small, since it is in the feedback loop. In addition, having a fairly large value capacitor at the output allows the driving of capacitive loads without instability, the low output impedance being of advantage at high frequencies.

Analysis points to an important result. Overall noise is inversely proportional to the square root of the number of voltage references: $E=E_n/\sqrt{n}$, where E_n is the individual noise of a reference.

Using the Burr-Brown *REF 10* with E_n= 10μV pk-pk in the circuit of Fig.2 gives an overall noise of less than 7μV pk-pk.

Kamil Kraus
Rokycany
Czech Republic

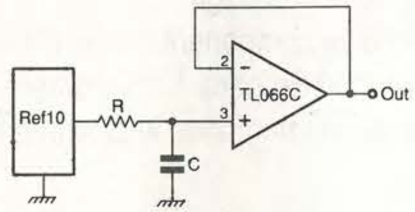


Fig. 1. Commonly used voltage reference circuit. Problems with this layout are capacitor leakage and buffer noise.

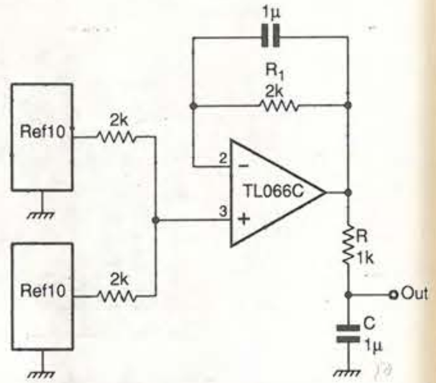


Fig. 2. Modified circuit with the leakage inside the feedback loop and noise reduced by two references.

WINNER TTI PROGRAMMABLE BENCH MULTIMETER

Loop aerial cuts through the noise

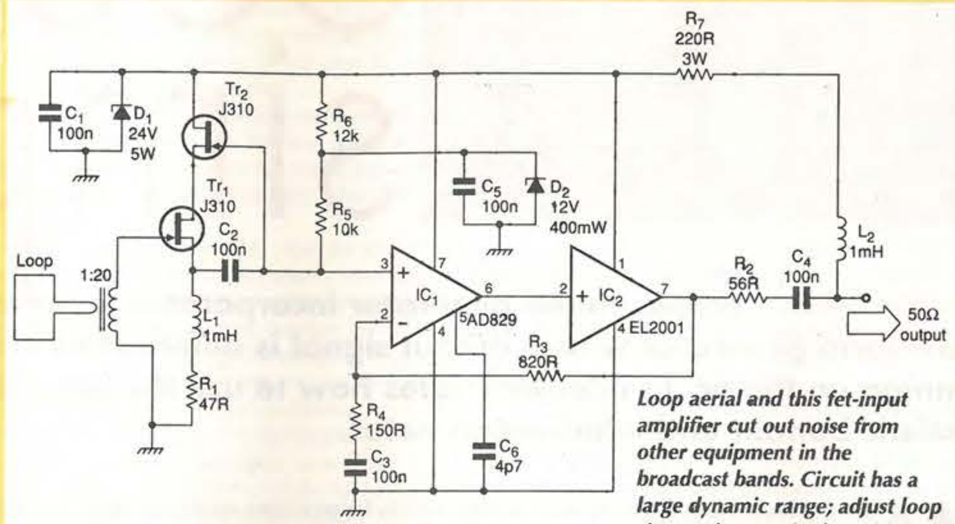
To allow the reception of long and medium waves in an environment polluted with computers and television receivers, this loop aerial and its amplifier, working with a 1m square maximum loop, reduce noise to the background level of the bands.

The business end of the circuit is formed by the input transformer and fet source follower; at long- and medium-wave frequencies, fets show low noise figures at 10kΩ source impedance. Transistor Tr_2 bootstraps out the gate/drain capacitance of Tr_1, the gate/source capacitance being low due to the follower configuration.

Maximising input transformer ratio while keeping shunt capacitance low results from the use of a toroid (*Cirkit* 55-40001 or *Fair-Rite* 26-43540001) with two primary turns of audio screened cable with the screen grounded at one end, and 40 on the secondary.

The op-amps form a low-noise amplifier driving a 50Ω cable and the other components form a phantom power supply, although a local supply could be used, in the 25-40V range.

J A Burnill
Camberley
Surrey



Loop aerial and this fet-input amplifier cut out noise from other equipment in the broadcast bands. Circuit has a large dynamic range; adjust loop size to give required sensitivity.

ILLUSTRATION JAMEL AKIB

Sounds simple

Ian Hickman's simple sound generator incorporates an eprom-based waveform generator whose output signal is determined via a Basic routine running on the pc. Ian demonstrates how to use the generator to produce realistic bottom-end wind-organ notes.

With a sound card in your pc, experimenting with synthetic sounds is straightforward. But there are still benefits in terms of versatility from a small stand-alone circuit, that can be hooked onto – or even into – something else. Here I describe a simple system for generating synthetic sound waveforms.

The circuit was to be minimal and preferably use only common ICs. The arrangement, **Fig. 1**, was made up on an odd piece of 0.1in matrix prototyping board. It consists of a uv-erasable eprom, containing data defining the waveform of the sound, reading out its contents sequentially to a d-to-a converter, which reconstitutes the intended sound.

How it works

The eprom address is simply obtained direct from a ripple counter, with one minor modification. The three-inverter oscillator drives the clock input of a *CD4040* twelve-stage ripple counter, the twelve outputs of which drive the A_{0-11} address lines of the prom.

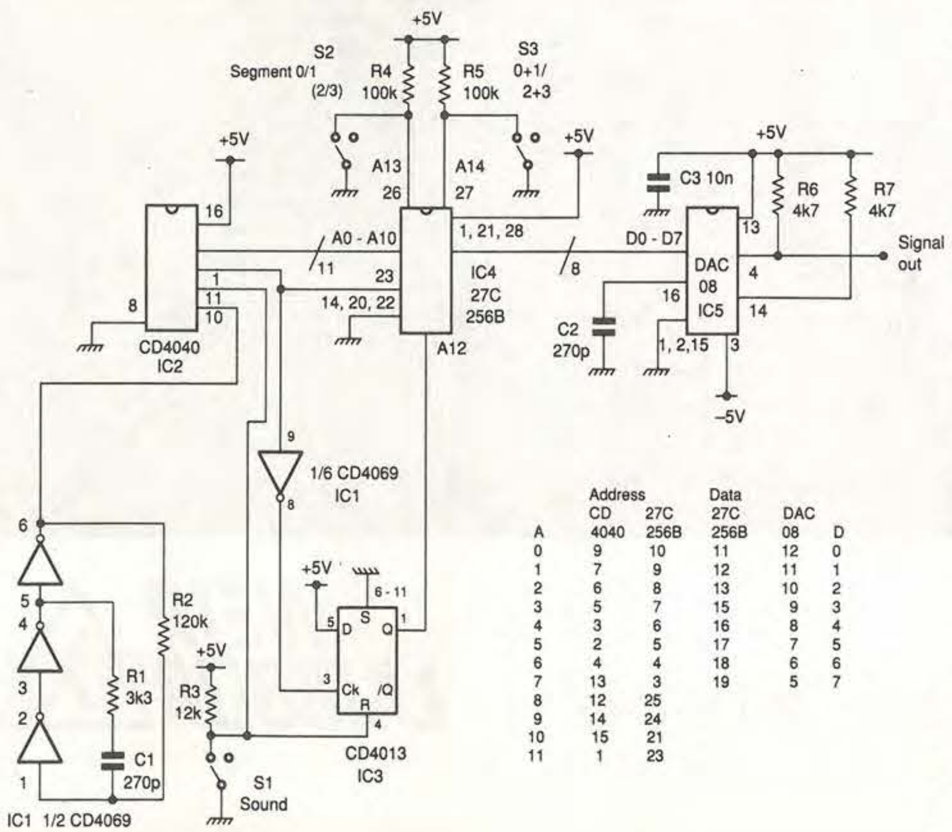
When the normally open push-button S_1 is pressed, counting starts from all zeros. The twelfth, most significant, bit toggles the *CD4013* D-type bistable IC, via an inverter, on its falling edge. Thereafter, A_{12}, the thirteenth address line to the prom, stays high until the button is released.

The result is that the prom initially reads out the data starting at location 0000, through location $0FFF_{16}$ and on to $1FFF_{16}$, after which it repeatedly reads out the data in locations 1000_{16} to $1FFF_{16}$ as long as S_1 remains closed. When S_1 opens, ICs 2 and 3 are reset, and all address lines return to logic zero. That at least is what happens if S_2 and S_3 are both closed. In fact, the prom is a *27C256B* device with a 256Kbit or 32K-by-8 capacity. Switches S_2 and S_3 control address bits A_{13} and A_{14}, effectively partitioning the prom into four segments of 8Kbyte each. Thus the prom is capable of storing four different sounds, any one of which may be called up, according to the settings of S_2 and S_3. With component values shown, the clock oscillator runs at 16kHz.

Many sounds have a characteristic starting transient, and this is stored in the first 4Kbyte half of a segment, the steady-state sound being held in the second half. Thus each sound is reproduced with its own characteristic start-up.

The data input to the d-to-a converter is converted to a series of dc levels, each lasting for one period of the clock. The d-to-a converter reference current I_{ref} is defined by R_7, the minimum value of I_{out} at pin 4 being zero, and the maximum being $I_{ref}\times 255/256$. Its complement, /Iout at pin 2, is not used, being spilled to ground.

Current I_{out} flows through R_6, the output voltage being therefore in the range +5V down very nearly to ground. It should therefore be ac coupled when applied to an amplifier, but when viewed on an oscilloscope, the expected dc coupled average voltage is of course +2.5V.



	Address		Data		
	CD	27C	27C	DAC	
A	4040	256B	256B	08	D
0	9	10	11	12	0
1	7	9	12	11	1
2	6	8	13	10	2
3	5	7	15	9	3
4	3	6	16	8	4
5	2	5	17	7	5
6	4	4	18	6	6
7	13	3	19	5	7
8	12	25			
9	14	24			
10	15	21			
11	1	23			

Fig. 1. Simple synthetic sound system in its entirety, with the counter on the left, the eprom in the middle and the d-to-a converter on the right. Clock generation is carried out by the string of gates bottom left and control by the switch and bistable IC next to it. Operation of the switches and control of oscillator frequency could easily be automated.

Using the sound generator

The circuit can be used to reproduce a sustained sound, complete with its characteristic starting transient, or, by storing sound in just the first 4K of a segment, a short transient sound. In the latter case, all locations in the unused second 4K of a segment should be loaded with the value $7F_{16}$ i.e. 127 decimal.

The 127 value represents the mean level of the waveform, allowing a peak output of ±127 least-significant bits relative to this.

A falling minor third

A frivolous example of a non-recurring sound would be the call of the cuckoo, a falling minor third. Each note is about a third of a second long, separated by a similar interval.

Played back over a loudspeaker in a tree at an improbably early date in spring might bring a claim to hearing it first in the local paper. However, my interest was in a more specific application, and I have written a program in Turbobasic to generate the necessary eprom data.

I was interested in trying to simulate the tone of an open flue pipe, as found in an organ in one of our cathedrals or large churches. As with most musical instruments, this has a characteristic start-up. In the case of a flue pipe, this is known as 'chiff'.

In fact most musical instruments are recognised principally by their initial transient; if you come in after the sound has started, it is often difficult to identify which instrument it is.

With an open-flue pipe, the initial transient consists of three separately identifiable parts. When a key is pressed, opening the pallet which admits air to the pipe, the first sound to appear is the noise of escaping wind. Then the pipe starts to sound, but typically it initially tends to 'overblow', producing the second harmonic. These two components are the chiff, which then subsides, to a greater or lesser degree, as the sound of the fundamental builds up to the steady state volume.

List 1 is the latest version of a program (which is still subject to further development) to produce a waveform sounding like a typical flue pipe. To keep the listing short, all the original remarks have been removed, and some lines telescoped – hence the gaps in the line numbers sequence.

Basic produces organ data

The program consists of two parts: lines 100 to 440, and 1000 to the end. The GOTO at line 130 means that normally, only the second part executes. This draws a picture of the waveform that will be generated, on the screen.

Lines 1010 and 1020 set up the display to read in X and Y co-ordinates of 0 to 399 from left to right and from bottom to top. The next line initialises some parameters, and the following one starts the main execution loop.

Line 1050 defines an amplitude envelope E1 for the fundamental. This builds up linearly to a maximum amplitude of 40 – or such other value as set by parameter T – over points 0 to 199, i.e. the left hand half of the screen, thereafter remaining at that amplitude. The next line defines a sinewave F1 (the fundamental) with thirty two steps per cycle and multiplies it by E1, to give the enveloped fundamental F. Given the 16kHz clock frequency and thirty-two steps per cycle, the frequency of the fundamental is 500Hz.

Lines 1080, 1090 do the same for the second harmonic H, except that the envelope builds up linearly to value T over the first quarter of the screen, and then dies away linearly by half way across, a 'diamond-shaped' envelope.

Lines 1110 to 1200 are concerned with the wind noise element of the sound. This is the part that proved most problematic, and is responsible for the program being at version 6 – not counting some unrecorded intermediate versions.

But the original wind noise envelope E3 has basically remained unchanged throughout. It consists of a diamond shape like the second harmonic envelope, but occupying only the first quarter of the screen, rather than the first half, and reaching a maximum amplitude of only $T/2$.

The first attempt at wind noise simply called up 'diamond' enveloped random numbers, but this noise proved far too wideband, extending up to about sixteen times the frequency of the fundamental. It was a resounding failure, sounding quite unrealistic. So it was low pass filtered by taking a running average of successive random values, initially over 16 points. This was also a failure and I suspected that the noise should be band-pass limited by a formant introduced by the pipe itself.

The noise was therefore band limited to a much lower low-pass filter cut-off, by averaging over 128 samples, equivalent to four complete cycles of the fundamental. The DIM M(128) instruction in line 120 dimensions an array of 128 numbers. The loop then fills it with 128 random values each in the range –1

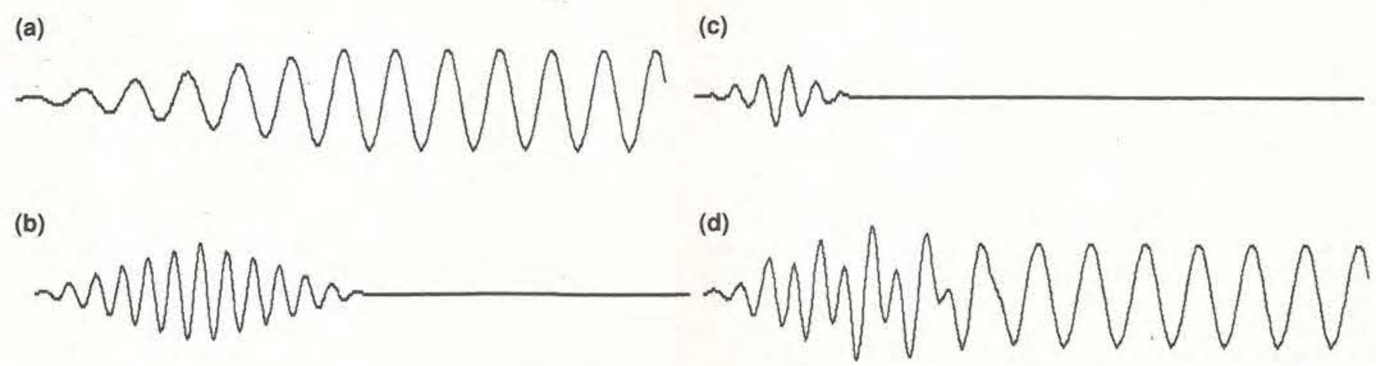


Fig. 2. Waveforms produced for the S^2S^2 by the Basic program listing. a) is enveloped fundamental, b) is enveloped second harmonic, c) is enveloped bandpass noise and d) the complete waveform.

to +1, ready for use by either part of the program. The low-pass filtered noise was multiplied by the fundamental, to give double sideband suppressed carrier bandlimited noise centred on *F*. While an improvement, it still did not sound right.

The low-pass filtering is achieved by lines 1120 to 1200. The value of a random number returned by RND(1) is in the range 0 to 1, and line 1120 modifies this to a number in the range –1 to +1. The new value of random number N is loaded into element M(K) of the array M, where K starts off at 0.

The next line sums the 128 elements of the array to give a new random number Z. Clearly, Z can at most change from one point to the next by only $^1/_{128}$, thus severely slew rate limiting it, equivalent to low-pass filtering.

At the next turn round the I = 0 TO G loop, the random number is loaded into the next array element (since *K* was incremented at line 1200), replacing the number previously there. Thus as each new random number is entered into the array, an old one drops out.

In line 1170, the low-pass filtered noise value Z is adjusted in amplitude, multiplied by the second harmonic (as this was found to sound much more realistic than using the fundamental) and then diamond enveloped.

The three lines 1220 to 1240 provide the facility to turn off the fundamental and/or second harmonic and/or the wind noise component W3, by removing the REM: at the beginning of the appropriate line.

The following lines 1250 to 1280 sum the two chiff components with the fundamental, check to see that the amplitude is not excessive, truncating it if necessary. They draw on the screen a line joining the previous 'voltage level' D1 to the current level D2, centred about a mean level of 127. The screen had previously been cleared by the CLS at line 110.

Variable D2 is then redefined as D1 and Z zeroed ready for the next turn around the main loop, after which execution returns to line 1040 ready for the next value of the loop counter I.

Finally, before ENDing, the program draws limit lines at the minimum and maximum permissible values of the waveform, at levels zero and 255. This shows whether the value chosen for the parameter T leads to excessively large 'voltage excursions', corresponding to numbers too closely approaching the limit values of 0 and 255 which can be stored in the eprom.

List 1. Basic program listing for producing flue-pipe organ tone data on a pc. Once produced, the data is down-loaded into an eprom. With suitable modifications, this routine could be used to produce and display data for other applications.

```
100 REM: LISTING TO PRODUCE FLUEPIPE ORGAN TONE DATA FOR PROM
110 CLS
120 DIM M(128): FOR P = 0 TO 127: M(P) = 2*RND(1)-1: NEXT P
130 REM: GOTO 1000
140 OPEN "PROML.BIN" FOR BINARY AS #1
150 K = 0: Z = 0: T = 40: G = 8191
160 FOR I = 0 TO G
170 E1 = I*2*T/G: IF E1 > T THEN E1 = T
180 F1 = SIN(6.283185*I/32): F = E1*F1
200 E2 = I*4*T/G: IF E2 > T THEN E2 = 2*T - I*4*T/G: IF E2 < 0 THEN E2 = 0
210 H1 = SIN(6.283185*I/16): H = H1*E2
240 E3 = I*4*T/G: IF E3 > T/2 THEN E3 = T - I*4*T/G: IF E3 < 0 THEN E3 = 0
250 N = 2*RND(1)-1: M(K) = N
270 FOR Y = 0 TO 127: Z = Z + M(Y): NEXT Y
300 W1 = Z/10: W2 = W1*COS(6.28*I/16): W3 = W2*E3
330 K = K + 1: IF K > 127 THEN K = 0
350 D = F + H + W3 + 127
360 IF D > 254 THEN END: IF D < 1 THEN END
380 D = INT(D)
390 D% = D
400 PUT$1, CHR$(D%)
410 PRINT I,D%
420 Z = 0
430 NEXT I
440 CLOSE #1
1000 REM: DRAWS ABBREVIATED VERSION OF WAVEFORM ON SCREEN
1010 SCREEN(2)
1020 WINDOW (0,399)-(399,0)
1030 K = 0: D1 = 0: T = 40: G = 399
1040 FOR I = 0 TO G
1050 E1 = I*2*T/G: IF E1 > T THEN E1 = T
1060 F1 = SIN(6.283185*I/32): F = E1*F1
1080 E2 = I*4*T/G: IF E2 > T THEN E2 = 2*T - I*4*T/G: IF E2 < 0 THEN E2 = 0
1090 H1 = SIN(6.2831853*I/16): H = E2*H1
1110 E3 = I*4*T/G: IF E3 > T/2 THEN E3 = T - I*4*T/G: IF E3 < 0 THEN E3 = 0
1120 N = 2*RND(1) - 1: M(K) = N
1140 FOR Y = 0 TO 127: Z = Z + M(Y): NEXT Y
1170 W1 = Z/10: W2 = W1*COS(6.28*I/16): W3 = W2*E3
1200 K = K + 1: IF K > 127 THEN K = 0
1220 REM: F = 0
1230 REM: H = 0
1240 REM: W3 = 0
1250 D2 = F + H + W3
1260 IF D2 > 127 THEN D2 = 128: IF D2 < -126 THEN D2 = -127
1280 LINE (I,D1 + 127)-(I+1,D2 + 127)
1290 D1 = D2
1300 Z = 0
1310 NEXT I
1320 LINE (0,0)-(399,0)
1330 LINE (0,255)-(399,255)
1340 END
```

Crunching numbers for PROM

When one is satisfied that the waveform looks right – and that the second half of the program runs properly – the GOTO at line 130 can be rendered ineffective by prefixing it with REM:, and a set of numbers calculated, for later blowing into eprom.

The first half of the program works in basically the same way as the second, with the following differences. Line 140 instructs the machine to open a binary file of the given name, with the extension .BIN, and assign it the label #1 (#2 or #3, etc, would be used if other file(s) were already open).

A binary file is one in which you can store bytes in sequence, starting at 'location 0', the first byte of the file. A location counter – automatically initialised to zero – is implicit, and is automatically incremented each time a write to the file (line 400) is effected.

In line 150, the length of the file is defined by G as 8192 bytes long, as distinct from the mere 400 bytes used when drawing a shortened version of the waveform to screen. Due to the use of parameters rather than constants, in lines 180 to 240, the same formulae as in the second half can be used. As there, they will produce an envelope that ramps up over half the value of G for the fundamental, corresponding to the first 4Kbyte of an 8Kbyte prom segment.

Similarly, the harmonic and noise transients extend over the first 4K and first 2K address ranges respectively. Line 350 calculates the actual value (to be later loaded into prom) for this ram location, and the next line aborts program execution if it is outside acceptable limits – just in case your latest modification to the second half of the program has not been accurately mirrored in the first. This is a useful precaution, as on an older machine (I was using a Compaq *Deskpro 386n*) the first part of the program is distinctly tardy.

For the same reason, line 410 is included as a comfort measure, to assure you that the program is still running and has not hung. Lines 380 to 400 take the integral part of D, define it as an integer variable, and write it to the next file location in ram.

Variable Z is then zeroed and the loop repeats until I=8191, when the binary file is closed and the second half of the program draws the abbreviated version of the waveform on the screen.

Sufficient significant figures for the value of pi have been included to ensure that the final value, in location 8191 is 127, the same as in locations 0 and 4095. Without this precaution, I found that although the sinewave 'joined up' when repeatedly cycling around the second 4K of a segment, some of the intermediate values (near the peak of the sinewave, where the value is almost stationary) suffered a change in the least-significant bit at around 6K, giving a slight but perceptible change in tone colour every 64 cycles

Storing the data

When a version of the waveform had been produced in a binary file in ram, it was loaded into an 8Kbyte segment of a 27C256 eprom. This was done at the pc using a Stag *Stratos* eprom programmer. This neat little device consists of two parts, connected by a ribbon cable umbilical. A half length board fits in a standard slot, using just the XT connector, while the other unit sits alongside the pc, and carries a 32 pin zero-insertion-force) socket.

The simple controlling software runs under DOS and does its best to look after you – whatever you do. On running the software, it requests you to disable NUMLOCK, and then awaits your command. One then selects the maker and type number of the prom to be programmed, sets the address limits (any required section of the prom can be programmed without affecting the rest) and loads the required data to the ram area used by *Stratos*. In my case, this was in binary format, other options being Intellec and Motorola S-Rec formats.

The prom was then fitted in the zero-insertion-force socket, and since it had only 28 pins, the far pins of the socket were unused. The machine was then instructed to check that the eprom was blank, which also prompts a test for correct connection. If the device is absent or misconnected (back to front or not in the subset of pins nearest to you), a red led on by the zero-insertion-force socket flashes and a warning message appears on the screen.

The program prom option was then selected. The machine checks the programmed prom against the ram data automatically, and a checksum is flagged up. Other available options include load ram from prom, display ram and edit ram, etc.

And did it work?

As far as the program is concerned, after curing the many silly mistakes in each of the various versions – yes. Loading the data into prom was straightforward, and prom FLUEPIPE1 was soon ready for testing.

The four available segments held enveloped fundamental alone, enveloped harmonic alone, enveloped noise alone and in the final segment, all three sounding together.

As recorded earlier, the version with white noise was totally unrealistic, and after erasing the prom, a modified version with low-pass filtered noise proved not much better.

Some more proms having been acquired, further versions followed, culminating in the prom FLUEPIPE3, with the low-pass filtered noise modulating the second harmonic.

Figures 2a), b) and **c)** show the enveloped fundamental, second harmonic and noise respectively. Now c) may look simply like a shorter version of b), but in fact it sounds quite different. Note that Fig. 2 shows screen dumps of the abbreviated waveform drawn on the screen, whereas the actual second harmonic, noise, and fundamental envelopes extend over about twenty times as many cycles.

The low-pass noise modulating the second harmonic is bipolar, so that the harmonic suffers random 180° phase changes. Thus on average, there is no second harmonic energy present, only double sideband noise extending either side.

The sound of this is rather like blowing across the top of a milk bottle, without actually getting it to sound a note – narrow band-limited white noise.

Figure **2d)** shows the complete waveform. In the prom version, the end joins up seamlessly with itself at location 1000_{16}, giving the sustained note when S_1 is held closed. It really sounds realistic, and should sound even better with some further tweaking.

For instance, the fundamental build-up is a little too slow – easily fixed in lines 170 and 1050 by changing the numeric multiplier in E1 from 2 to something larger. And a real flue pipe shows some second harmonic and noise even in the steady state, so E2 and E3 can be modified to die away to a finite value, rather than zero. And of course, the clock rate of 32 cycles per cycle of fundamental, provides for the inclusion of harmonics up to the sixteenth in the mix, permitting a variety of other tone colours to be produced.

While sounding fine at 500Hz, if the clock frequency is changed to give an output at 64Hz, the mix is found to be definitely wrong. The build-up of sound then needs to take place over far fewer cycles than at 500Hz, while the wind noise needs to be centred at a higher frequency than the second harmonic. This would fit the system for use as a generator for a monophonic pedal board for an electronic organ.

Organ music very seldom demands the playing of two notes simultaneously on the pedal board, so a one-note-at-a-time system, in the interests of economy, is an acceptable compromise. The pedal board could select tappings from a string of resistors, providing a potential applied to a voltage-to-frequency converter driving the address counter.

Thus the prom would provide each note at the appropriate pitch, with IC_2 and IC_3 reset when the voltage was absent.

Other uses

The circuit is clearly easily modified for other purposes. If only a single type of sound is required, S_2 and S_3 may be omitted, and a 64Kbit prom used. Alternatively, extra address counter stages could be added, enabling the whole contents of the 256Kbyte prom – or even a half or 1Mbit prom – to be played back.

If a sound of fixed, finite length is needed, then S_1 can trigger a set-reset bistable device, and the trailing edge of the most significant address line can reset it, re-applying a reset signal to IC_2. One could even add an a-to-d converter, latch and ram, driven from the address counter, enabling sounds from a microphone to be captured, transferred to pc and stored in prom. ■

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ACTIVE

A-to-d and d-to-a converters

8-in-1 d-to-a converters. *MP7610 Series* contain eight digital-to-analogue converters with voltage output amplifiers. Operation is such that ground currents dependent on code and reference voltage variation are eliminated; this also ensures accuracy of matching between converters, which means that only one full-scale value need be calibrated. *MP7610/1* devices are 14-bit types and the *MP7612/3* are 12-bit converters; *MP7610/1* have serial data/address control logic and the other two a parallel interface. Outputs swing ±10V, sinking or sourcing 5mA and settling to 12 bits in under 30µs. METL. Tel., 01844 278781; fax, 01844 278746.

Discrete active devices

Diode rf switches. *LMS33* sub-miniature, surface-mounted, ceramic rf diode switches by Murata are intended for use in wireless lans and cellular telephones. There are two versions with and without an integrated low-pass filter and both are contained in a ceramic package measuring 5.4 by 4 by 2.8mm. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Linear integrated circuits

Power control. International Rectifier's *IR215X* family of control ics now includes two new components, the *IR2153/4*, for use in half-bridge power converters. Features of the new devices include, for fluorescent lighting, start-up from a high-voltage rail with a dropping resistor using the micropower and zener-clamped Vcc supply and a shut-down mode. There is also pre-heating and open-lamp protection. For use in ac/dc adaptors and consumer supplies, there is a resonant circuit and zero-voltage switching. The devices are pin-compatible with the IR2151/2. International Rectifier. Tel., 01883 732020; fax, 01883 733410.

Memory chips

4Mbit cache rams. Hitachi has two 125MHz 4Mbit synchronous cache srams for second-level cache memory in workstations using Sparc cpus. *HM67S36130*, which is a 128K by 36 device and the *HM67S18258*, a 256K by 18 type, are register-to-latch mode ssrams with a 7ns initial access time. Both are 3.3V srams with low-power lvcmos-compatible i/o. Byte write control allows the cpu to write several lines of data at a time for increased flexibility and a self-timed late write function simplifies design by eliminating the need for a write control pulse. Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160.

64Mbit dram. NEC's 64Mbit 3.3V cmos drams come in a choice of ×4, ×8 and ×16 configurations. Three versions are available: *µPD4264165/5165* are 4M by 16bit types in 50-pin TSOP for surface mounting; *µPD4255805/4805* 8M by 8bit versions and *µPD4265405/4405* 16M by 4bit devices, all in 32-pin TSOP or SOJ. Versions with access times of 60ns and 50ns are now available and 40ns types are to come later; the edo mode allows cycle times of 20ns and there are devices with fast page mode operation. Refresh modes include ras only, ras before cas and hidden refresh. Sunrise Electronics Ltd. Tel., 01908 263999; fax, 01908 263003.

Microprocessors and controllers

Low-power micro peripherals. WSI offers the *ZPSD3XX* family of 'zero-power', 2.7V and 5V programmable microcontroller peripheral ics, in which one chip contains up to 2Mb of eprom, 16Kb of sram, programmable memory map address decoder, a glueless logic controller interface and programmable i/o ports. The 2.7V versions draw 1µA in standby and 0.4mA per megahertz of bus frequency; 5V types 10µA and 0.8mA. Silicon Concepts Ltd. Tel., 01428 751617; fax, 01428 751603

Optical devices

Optocoupler. Isocom's *4N32-1* optically coupled isolator is based on the standard *4N32*, but produces a current transfer ratio of 800 for a 1mA drive current, against the 10mA of the standard type; even with a 0.25mA drive, the ratio is still 200 and saturation 1V. It is packaged in a 6-pin dil for through-hole or surface mounting, isolation being to 5kV rms. Access to the output darlington base allows adjustment of the ctr. Isocom Components Ltd. Tel., 01429 863609; fax, 01429 863581.

PASSIVE

Passive components

Chip resistors. Philips' *ARC241* array chip resistors have values in the range 10Ω to 1MΩ at ±5% in the E24 series. They are on a high-grade ceramic body, internal electrodes at each end connected by resistive paste, the composition of which is varied to give approximate resistance value. Laser trimming then achieves the final value. Temperature coefficient is $<200\times10^{-6}$/K, power dissipation 0.062W and maximum voltage 50V, dc or rms. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Tantalum capacitors. Tantalum, surface-mounted capacitors with low equivalent series resistance are offered by Dubilier. Components in the *SHJL* range handle higher ripple current with lower ripple voltage and heat dissipation than standard types. Minimum esr is 65mΩ and values are in the range 4.7µF to 470µF at ±10% or ±20% tolerance, leakage current being <0.01CV or 0.5µA. Dubilier Ltd. Tel., 01371 875758; fax, 01371 875075.

Chip inductors. Murata's *LQP11A/21A* series of coils provide a tolerance of ±0.2H or ±2% even at low values. Low stray *Cs* confer high self-resonant frequencies and the components are stable. They can be soldered using both flow and reflow techniques. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Low leakage tuning diode. Zetex's *ZC829A* variable-capacitance diode, intended for use in pagers, cellular telephones and vcos, exhibits a reverse leakage current of 200pA at 25V. At 2V bias, capacitance is 8.2pF, making it suitable for vhf/uhf work, C having a ratio of between 4.3 and 5.8 for an input voltage of 2-20V. Maximum forward current is 200mA, power 330mW at 25°C. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

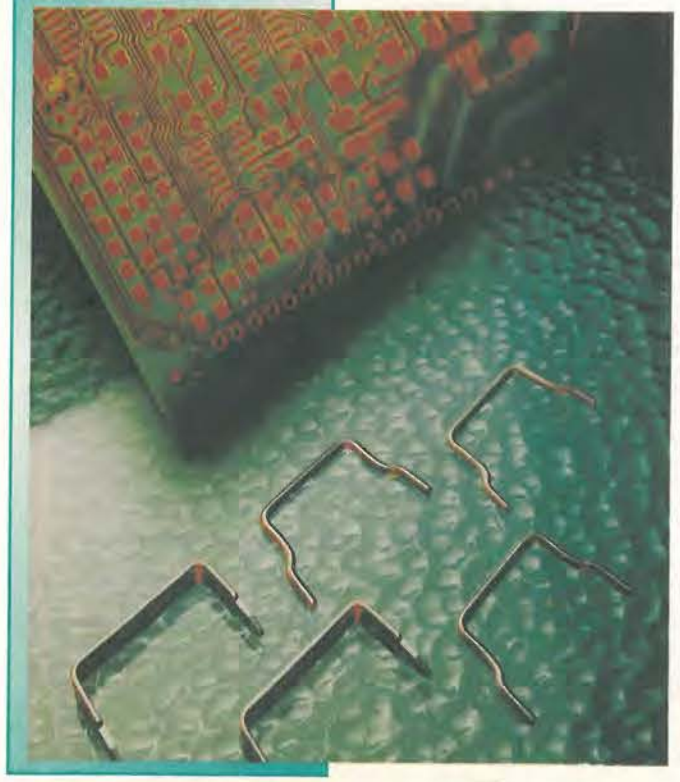
Suppression capacitors. Samwha *SC* disc ceramic capacitors for Classes X1 and Y2 use, are mains suppression types for 250V ac. Values from 100pF to 10nF ±10% are available to cope with line harmonics or spikes across the line or live/neutral to earth. *SD* series components are for Classes Y1 and X1, also for 250V ac come in values from 100pF to 4700pF. All are approved to EN132400 and FIMKO IEC 384-14. Easby Electronics Ltd. Tel., 01748 850555; fax, 01748 850556.

Audio products

AC '97 audio codec. *HMP9701*, an audio codec for pcs from Harris, meets the analogue requirements of the Audio Codec '97 (AC '97) specification and is believed to be the first in the field, providing d-to-a conversion, a-to-d conversion, mixing and i/o. It includes 16-bit stereo full-duplex operation at 48ksample/s for four analogue line-level stereo inputs for connections from line, cd, video and auxiliary, all with individual gain control. Two analogue inputs are present to connect speakerphone or line 'phone and beep and a mono microphone can be switched between two external sources. The output offers more than 90dB s:n ratio. A mixer manages playback and recording of the digital and analogue sources likely to be present, including system audio for business, games and multimedia; microphone, speakerphone, stereo line in; video; and auxiliary/synthesiser. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Connectors and cabling

USB connectors. Jack and plug connectors, part of Harting's *har-mik* range, comply with the standard USB format, in which a single USB port replaces the serial and parallel connections now in use, with 'plug-and-play' compatibility and hot-swapping. Connectors for the bus are available in rectangular and square form and dual-stack types. Voltage rating is 30V rms and current rating 1A per contact. Harting Elektronik Ltd. Tel., 01604 766686; fax, 01604 706777.



Low-value resistors. Modulohm has a range of very low value resistors in the form of an uninsulated band or wire and covering the resistance range 5.4mΩ to 100mΩ. They are intended for use in power supplies and regulators and customers' needs for height and width can, for the most part, be met. Self-inductance is extremely low and the components are easy to mount. Kestronics Ltd. Tel., 01727 812222; fax, 01727 811920.

Pc card connectors. Fujitsu Takamisawa's new range of Type I, II and III PC card connectors, the *FCN 560 Series*, offers the option of through-hole or surface mounting and either low-profile or lifted housings, which allow the mounting of components under the header; there are also types to mount below the board. The range includes single and double stacked card headers with push-button ejectors either side. Young-ECC Electronics. Tel., 01628 810727; fax, 01628 810807.

Right-angled sub-D connectors. Erni has a new set of sub-D connectors for right-angle press fitting in both socket and pin versions in standard and European designs (7.3 and 3.6mm in height respectively). They are available with 9, 15, 25 and 37 poles and lock with screws, using standard press-fit tools into 1mm holes. The black insulating body is in glass-fibre reinforced plastic which is shrouded in tin-plated steel; contacts are in gold-plated copper alloy. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Screened IEC mains connectors. Schurter's *Groundfit* IEC mains connectors are enclosed in an emc shield, which is said to offer unprecedented screening in a package measuring only 24mm deep. In addition, the *GRF4* model has a low-impedance mains filter to guard against line-conducted interference. The connectors snap into the inside of a panel with no need for mounting tools. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Microphone cables. Professional and deluxe microphone cables from Alcatel are new to Wadsworth's catalogue. The professional type is a balanced cable with flexible pvc outer and a cotton filling to help keep its shape and therefore maintain constant capacitance and reduce handling noise. Pvc-insulated, 28 by 0.1mm stranded, plain copper wires are screened by a 1mm tinned-copper wire lap screen. Capacitance is 175pF/m and resistance 86Ω/km. The deluxe type has 102 by 0.05 stranded wire, 123pF/m and 94Ω.km resistance. Wadsworth Electronics Ltd. Tel., 0181 2686500; fax, 0181 2686565.

Mains plug tidy. Rendar offers a 'local power distribution system' – a box with four sockets and a plug to take EN360 connectors for audio gear, the fixed plug connecting the power from a mains socket. Quadbox has total rating of 10A and meets BS5733 standards, comes in black or white and in free-standing or screw-down versions. Rendar Ltd. Tel., 01243 866741; fax, 01243 841486.

Displays

Large, flat plasma monitor. Densitron's colour plasma display has a screen diagonal of 42in in the 16:9 format and is only 6in deep. It is immune to magnetic interference and any problems of linearity, geometry, convergence or focussing. A VGA interface allows connection to a pc and the built-in FBAS/S-VHS interface permits use as a video monitor. Viewing angle is 160° and resolution 852 by 480 pixels. Densitron Perdix. Tel., 01959 700100; fax, 01959 700300.

Protective windows. Wherever a keyboard with a display is to be used in the familiar 'harsh environment', these windows avoid damage to the display from liquids (even under pressure), grime and treatment generally to be regretted. The windows are made in polycarbonate, acrylic or toughened glass to any size, although the smaller, the stronger. They can be clear, coloured, provided with anti-glare treatment, polarised, protected against ultraviolet light and rf and emi. Rowland Automation Ltd. Tel., 01202 826398; fax, 01202 828205.

Filters

Emi/rfi filter. *VSSRC* thin-film resistor-capacitor filter networks are intended for emi/rfi reduction and filtering in power supplies. Components are on a single chip in two kinds of 20-pin, surface-mounting package. FET Electronics Ltd. Tel., 01635 524490; fax, 01635 552244.

Hardware

VME backplanes. Schroff has a range of high-speed VME 64X systembus backplanes for data transmission with fast drivers in accordance with VME 64 extension draft 0.8. Rates are 60Mbyte/s for J1/J2 backplanes and 120Mbyte/s for multiplexed block transfer. Backplanes are in eight layers with four separate signal planes having low crosstalk and a uniform 50Ω impedance on all signal lines. The five-row, 160-pin connectors are compatible with C96 F connectors to DIN 41612 (class 2-400 cycles). Termination resistors are on-board and daisy-chain signals can be passed on manually or automatically. Schroff UK Ltd. Tel., 01442 240471; fax, 01442 213508.

Solderless backplane. Backplanes by Teradyne, the *KS1025 Series*, use tuning-fork contacts, fitted to the backplane using the company's dynamic-retention method, which eliminates contact-to-panel soldering and thereby removes the need to comply with MIL-STD-2000. Insertion force using special low-force contacts is 50g per contact, allowing up to 400 contacts to be used. Backplanes themselves can be simple two-sided types up too multi-layer designs with copper interlayers for heavy current-carrying. Acal Electronics Ltd. Tel., 01344 727272; fax, 01344 424262.

Test and measurement

Down-to-earth tester. Practical Power produces the *Wrist & Heel/Toe Strap Tester*, which meets the relevant Directive, measuring the resistance of earthing straps on shoes, heel and toe straps by means of a wall station and footplate. You can mount it on a wall or carry it about; power comes from a 9V battery. Failure is indicated by a buzzer and a red led and the battery state is also shown. Practical Power Ltd. Tel., 0118 9699170; fax, 0118 9699171.

Portable recorder. Yokogawa's *DR130* portable multi-function recorder logs up to 20 channels of voltage or temperature data in analogue or digital form on a built-in chart and stores the data on its floppy-disk drive or PCMCIA card. Input voltage range is 1μV to 50V, signal conditioning being incorporated for all commonly used thermocouples and platinum temperature detectors; each channel is individually programmable. Accuracy is within 0.05% of reading and the temperature resolution is 0.1K. GPIB and RS232C interfaces are available and there is software to allow the pc to display and analyse data in a range of graphical forms. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

Lower-cost sig. generators. For less than £300 each, Kenwood has two low-frequency signal generators for colleges and schools. *AG-204* and *AG-203A* generate sine and square wave outputs over the 10Hz-1MHz range and include such features as external sync., 10dB/step attenuators and large frequency dials. *AG-204* offers 0.02% thd from 500Hz to 20kHz and 0.05% over 100Hz to 100kHz, the 203A, being cheaper, distorts by 0.1% between 400Hz and 20kHz and 0.3% from 100Hz to 100kHz. Feedback Test and Measurement. Tel., 01892 653322; fax, 01892 663719.

Telecomm line filters. *CM04* surface-mounted common-mode data line filters by Taiyo Yuden have a working voltage of 50V dc and are rated at up to 2.5A, depending on value. They are available with two, three or four lines and are in a plastic package measuring 6.3mm by 4.6mm maximum, with the length of 10mm maximum depending on the number of lines. Taiyo Yuden UK. Tel., 01494 464642; fax, 01494 474743.

Power meter. Hioki's *Model 3330* single-phase power meter measures ac power from 10Hz to 50kHz, voltage in three ranges of 150, 300 and 600V ac and current in eight ranges from 0.2A to 30A; integration permits watt-hour or amp-hour measurements to 10,000 hours. Its comparator function allows power measurement on a production line in 0.4s and an optional RS232 or GPIB interface allows printing or integration into an automatic measuring system. Telonic Instruments Ltd. Tel., 01734 786911; fax, 01734 792338.

Interfaces

USB interface. Without extensive redevelopment, the *USS-720 Instant USB* from Lucent Technologies enables the use of existing equipment on the new universal serial bus. It works as an intelligent controller, can be internal or external to an existing peripheral and initiates and manages the fastest protocol available to provide a bridge between USB and the IEEE 1284 parallel port. This asic, also available as an fpga, is part of the Lucent *Silicon Suite for USB*. Lucent Technologies Microelectronics Group. Tel., 01344 865910; fax, 01344 865923.

Literature

Fuses. Anglia can offer a 46-page catalogue of Bussmann fuses by Cooper Industries, whose range includes surface-mounting types, pin-indication fuses, in-line and blade designs and a range of accessories such as pc mounting, panel-mounting fuses and fuseblocks, clips, actuators and limiters. Some of these fuses withstand board washing and the colours don't come off in vibratory feeders. Anglia. Tel., 01945 474747; fax, 01945 474849.

Cables and connectors. CPC's 1997 catalogue contains descriptions of about 2000 new products. Over 450 new cable types are in from suppliers such as Alcatel, Alpha and Multicomp, covering a range of applications from test gear to heavy switching. More than 1500 connectors are now added to the range from AMP, Bulgin, DGS, Molex and Neutrik. Combined Precision Components plc. Tel., 01772 654455; fax, 01772 654466.

Low-voltage Directive CD-rom. More help on Directive navigation. This cd-rom is produced by GK Consultants and Technology International Inc., the complexity of the subject being indicated by the promise that it will help 'to begin to understand the LVD'. What you get is a copy of the cd-rom; a year's access to a Web site offering information down-loads of advice and report templates; and confidential answers to problems. A search engine locates references in EN60950 in a matter of seconds and you also get your 'very own virtual product safety engineer' (the bank manager in the cupboard again). You will need at least a 486 with Windows 95, 16Mb of ram, a cd-rom drive and a 16-bit sound card. G K Consultants Ltd. Tel., 01703 767739; fax, 01703 767789.

Components. Electrospeed offers its 1997 catalogue, which is concerned, apparently, with 'technical niche products'. This appears to mean that it is full of descriptions of racks and enclosures, interconnectors and power supplies, including batteries. It is free of charge. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

Design guides. *Arrow-Jermyn Designs*, now in its seventh 16-page issue, contains application notes from eight manufacturers, featuring the use of resistor networks, microcontrollers, video compression processors, programmable logic, optocouplers and memory. In this issue are pieces on the Bourns Mininet, one of the smallest resistor networks available, the *ADV601* video compression processor from Analog Devices and the *PIC12C5xx* microcontroller. Arrow-Jermyn. Tel., 01234 270027; fax, 01234 214674/791501.

Materials

Low-temp. seals. Samco's new silicone rubber compound for extrusion or moulding stays flexible at temperatures down to –115°C, against –60°C for the normal material. Samco Silicone Products. Tel., 01727 811877; fax, 01727 810728.

Epoxy resins. Resintech has introduced a range of resin-based products having a choice of packaging. The range includes adhesives with both standard and fast cure, encapsulants, sealants and material for cable and harnessing use. Packages are the *TwinPack*, in which the two components are separate and mix when a clip is removed, or *DuoSyringe*, in which they are in parallel cylinders and exit through a mixing nozzle. There is a range of surface preparation and handling aids. Resintech Ltd. Tel., 01285 712755; fax, 01285 713036.

Emc gaskets. Holland Shielding Systems bv has a new type of gasket that has a conductive seal for protection against 10kHz-35GHz radiation and water and dust. It is for application in grooves, flat, with or without a self-adhesive strip in sizes from 20 by 40mm to 2 by 2 meters, 1-20mm thick. The gaskets are endless and require a much lower compression than do O-rings. Holland Shielding Systems BV. Tel., 0031 78 6131366; fax, 0031 78 6149585.

Panel meters. Five models in the *Select* range of programmable digital panel meters are the *1000* series for ac/dc current/voltage, compatible with 5A current transformers; the *2000* series for process current and voltage signal; *3000* counter/totaliser; *4000* frequency and rate meter; and the *5000* temperature meter for both thermocouples and rtd. All have a 6-digit led display and fit a 1/8 DIN cut-out. They can all be supplied with analogue output cards and RS422 and RS485 comms ports. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Production equipment

Pcb inspection system. *VisionPoint* from DiagnoSYS is an automated inspection system for populated printed-circuit boards consisting of multiple cameras, lighting, a monitor and extensive, Windows 95-based software. A moving camera array 'sees' the fine detail on the board and compares the image with templates held in memory. Details of a perfect board are either 'trained' into the system or cad details are supplied to autotrain it at about one part per second. Once set up, the unit will inspect up to 750 components per minute on boards up to 18 by 20in. DiagnoSYS Ltd. Tel., 01730 7886219; fax, 01730 260659.

Power supplies

Inductorless dc-to-dc converter. Linear Technology's *LTC1263* switched-capacitor charge pump voltage converter produces regulated 12V at up to 60mA and 76% efficiency with no inductors from an input of 4.75V. It draws 320μA while working and a shut-down pin reduces that to under 0.5μA. The circuit is a charge-pump tripler with an internal oscillator, needing four small ceramic capacitors externally. Package is an SO-8. Linear Technology (UK) Ltd. Tel., 01276 677676; fax, 01276 64851.

Power supply controller. Micro Linear's *ML4902/3* converts a 5V or 12V supply voltage to a current of up to 14A at 1.8-3.5V, programmed by an

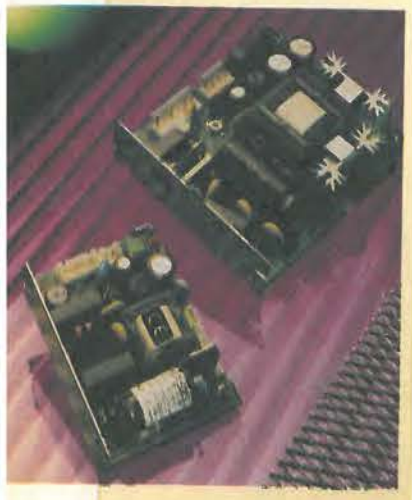
Please quote *"Electronics World"* when seeking further information

internal 5-bit control analogue-to-digital converter. Synchronous rectification is in use to provide higher efficiency than schottky rectifier buck converters and a dual feedback loop produces a 30A/µs transient response needed by fast processors. Ambar Components Ltd. Tel., 01844 261144; fax, 01844 261789.

Voltage references. *LM4040/41* ±0.1% shunt voltage references offer space saving in SOT-23, TO-92 and SO-8 packages, and come in a range of fixed and adjustable output voltages. Fixed voltages available are 2.5, 4.096, 5 and 10V, the *LM4041* having a fixed 1.225V or adjustable output. Operating current range is 60µA to 15mA. There is no need for a stabilising capacitor, even with a capacitive load. Solid State Supplies Ltd. Tel., 01892 836836; fax, 01892 837837.

Mains adaptors. *Egston Mainy* plug-top mains adaptors from Chloride Powerline are thought to be the world's smallest ac/dc power supplies, providing an output of 3-12W in a volume only slightly bigger than a 13A plug. They are available in mains adaptor or battery charger form and are compatible with UK, US or European requirements. A pc-mounting version is also available. Output voltages are 3, 6, 9, 12, 15 and 18V to within ±5% or ±1% for the 6W and 12W types. Typical efficiency for all versions is 70%. Chloride Powerline. Tel., 0118 9868567; fax, 0118 9755172.

Ac/dc converters. Melcher offers the *SWE* family of single-output power supplies, which are CE marked after being redesigned to conform with the LVD; they are also approved to US standards. There are six units providing outputs from 5W to 100W, all taking a single input range of 85-264V ac. Remarkably, the 5W unit is only 18mm deep and even the 100W type only 35mm. Melcher Ltd. Tel., 01425 474752; fax, 01425 474768.



Voltage regulators. *MIC5203* 80mA, low-dropout regulators in SOT143 packs are designed specifically for use in hand-held, battery-powered devices such as cellphones. Dropout is typically 20mV on a light load and 300mV at 80mA, with 225µA of ground current at 10mA out. Initial output is accurate to within 3% and the device has a cmos/ttl logic-compatible on/off input. There is protection against overcurrent and overtemperature. Output voltages available run from 3V to 5V in seven models. Solid State Supplies Ltd. Tel., 01892 836836; fax, 01892 837837.

Small, efficient dc converters. Melcher and Sextant Avionique have produced the *G-Family* of 88% efficient dc-to-dc converters that produce 25W from a package measuring 53 by 43 by 10.5mm over the standard –40 to 71°C temperature range with no additional cooling or heat sink needed. There are three outputs of 5V, 12V and –12V, which trade power output, from inputs of 8.4-36V dc, 14-36V dc and 36-75V dc. Start, power fail and shut-down can be sequenced and there is thermal monitoring. Also an 8-bit data stream allows a self-test routine and continuous monitoring for failure. Melcher Ltd. Tel., 01425 474752; fax, 01425 474768.

Radio communications products

S-m mixer. The *2109* surface-mounted double-balanced mixer is designed for 860-1500MHz input with 0dBm-8dBm, 820-1120MHz local oscillator drive. Conversion loss is 9dB, the intercept point 7dBm and the compression point –1dB, all with 3dB drive. Power output is 50mW into standard 50Ω impedance. Cirkit Distribution Ltd. Tel., 01992 444111; fax, 01992 464457.

Switches and relays

Thin relays. The *SNR* power relay from Schrack is 5mm thick, but still handles 6A at 250V ac. It can be fitted with one normally open or a changeover contact and the coil takes 170mW at 3-110V dc, the casing can be either fluxtight or immersible. These relays comply with all manner of standards and requirements. Schrack Components Ltd. Tel., 0181 868 1211; fax, 0181 866 2221.

Membrane panel selector. If you are after a membrane switch panel with the natural touch and find it difficult to specify, Tactus International has the answer — the *Tactus Switch Selector.* To avoid repeatedly going back to the drawing board to get the feel right for a particular application, you simply try out a number of test panels in the set supplied and specify the one you need. Tactus then guarantees to supply a panel to your design with the same actuation force, actuation point and bounce, as far as is possible. Tactus International Ltd. Tel., 01983 526535; fax, 01983 524964.

Transducers and sensors

Pressure transducer. EG&G IC Sensors' *Model 1210* general-purpose, solid-state, field shielded piezoresistive pressure transducer has been modified to improve the glazing on the ceramic and the metallisation near the laser fused links. The sensor covers gauge, absolute and differential pressure from 0-2lb/in^2 to 0-100lb/in^2 to ±0.1%, with 100mV output. There is integral temperature compensation and calibration over 0-50°C with laser-trimmed resistors, an additional resistor programming the gain of a differential amplifier to normalise pressure sensitivity variations. Eurosensor. Tel., 0171 405 6060; fax, 0171 405 2040.

Industrial selector switches. A complete range of selector or banner switches for panel mounting in control and instrumentation systems is available from EAO-Highland. It includes switches to handle signals from 10µA at 100µV to 5A at 500V, mounting in panel cut-outs from 16mm to 30.5mm diameter. Most switching formats are catered for in combinations of momentary and maintained operation in two or three positions, other selectors being available with up to 12 positions. The 16mm switches may have coloured windows in the knob and optional lighting. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Keyboard switches. Through-hole and surface-mounted miniature switches for keyboards in EAO-Highland's *Micro-Cosmos* range are 7.6mm square, stand 4.6mm high and mount on a 2.54mm matrix. Action is momentary single-pole, two-position, a dome actuator producing audible and tactile feedback. Silver or gold contacts are available, the gold type switching voltage down to 10mV at 500µA. Buttons are round, square or hemispheric domed and mount on front panels or under a film overlay. Hawnt Electronics Ltd. Tel., 0121 784 3355; fax, 0121 783 1657.

Card reader. Panasonic's *ZU9200* 'smart' magnetic card reader is one of the smallest available and is meant for cash-out tills and access control. It measures 148 by 62 by 41mm, is motor driven and offers the options of single or multitrack card reading and ISO-compatible smart/chip card reading and writing. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Silicon accelerometer. Endevco offers the *Model 7264B-500*, a piezoresistive accelerometer having a full-scale range of 0.8mV/g and internal stops to withstand 5000g shock in all axes. The device weighs 1g and is small enough to fit in a minute space. Mass, gauges and supporting rim are all formed from a single silicon crystal to eliminate zero shift and confer stability and repeatability. Phase shift is minimal and frequency response 0-3kHz, operating over the temperature range –40 to 93°C. A eight-metre cable is fitted as standard. Endevco UK Ltd. Tel., 01763 261311; fax, 01763 261120.

COMPUTER

Computers

Industrial computers. Anglia Technology is to handle the American Ziatech *CompactPCI* computers using the QNX operating system in 3U and 6U versions, the 6U types taking 14 peripheral cards without a bridge and 20 with one bridge. Processor in the 6U system is the *ZT5510 CompactPCI* Pentium running at up to 200MHz using the Intel Triton chipset and with up to 96Mbyte of EDO ram and 8Mbyte of flash memory. There is an enhanced IDE interface with an integrated drive as an option, a fast Ethernet interface and a standard set of peripherals. The system runs on the Universal Serial Bus – one of the first industrial computers to do so.

Data communications

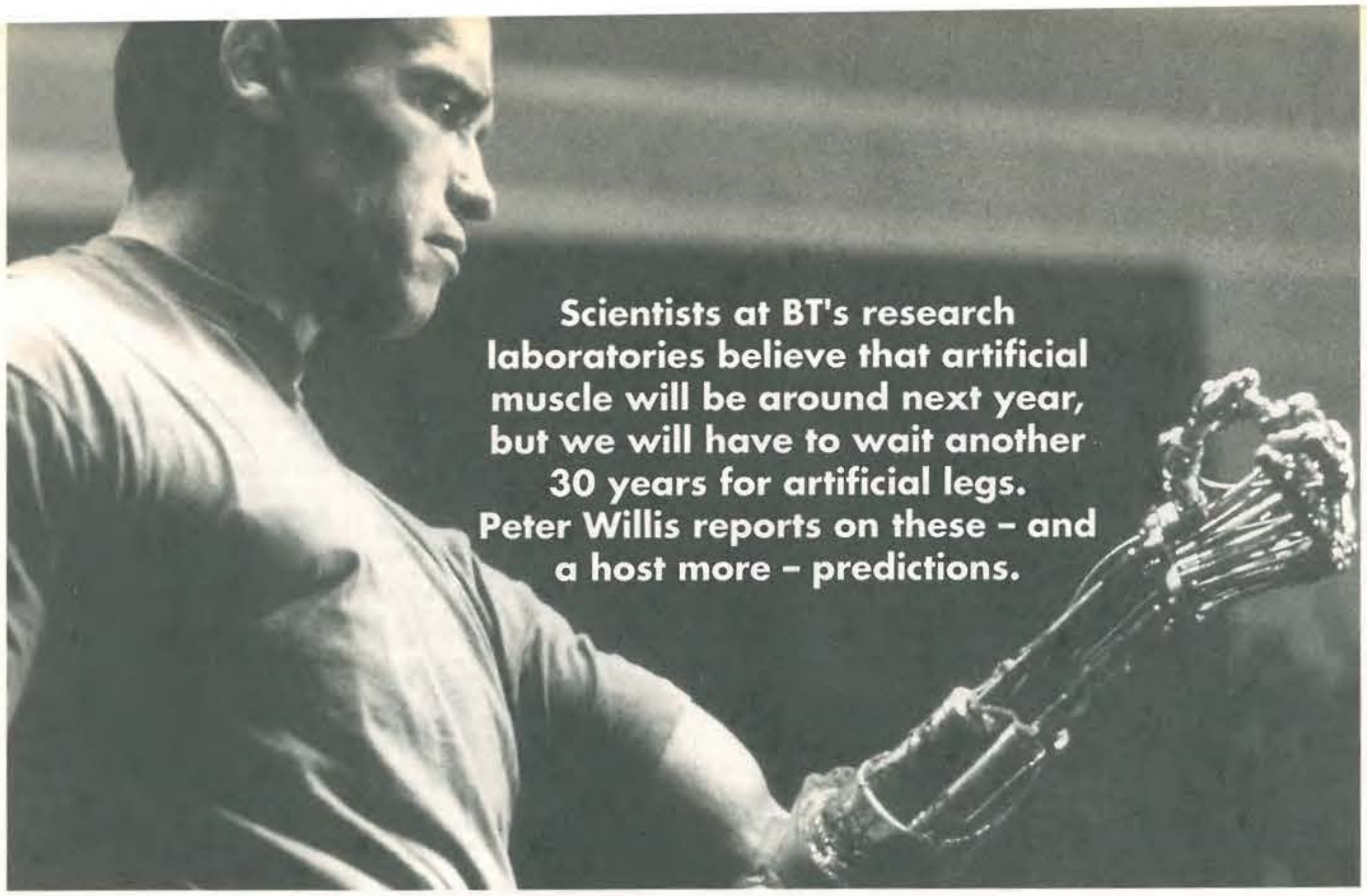
Hayes radio modem. Wood & Douglas announces the *HCM450*, a radio modem with a Hayes interface. It has a range of 20km line-of-sight and auto-dials up to 250 remote sites, each modem having a programmable source address used to detect incoming data packets from the others. The unit is in an IP65 enclosure and is type-approved for the UK delicensed telemetry band. Wood and Douglas Ltd. Tel., 0118 9811444; fax, 0118 9811567.

Modem. Latest addition to Rockwell's *SocketModem* range operates at up to 33.6kb/s with fax and receive speeds up to 14.4kb/s. It has the same footprint as all the others in the range (1 by 2.5in) and forms a complete V.34 data/fax/voice modem in a low-power module which simply mounts in a socket. Features include *AudioSpan*, which is simultaneous voice and data, and full duplex *Speakerphone*. There is an on-board line interface and firmware in rom. Error correction is to V.42/MNP2-4 and data compression to V.42bis/MNP5. A non-error-correcting code can be selected. Telecom Design Communications Ltd. Tel., 01256 332800; fax, 01256 332810.

Quad uart with fifo. A quad universal uart from Exar, the *82C684* provides four independent, full-duplex, asynchronous channels in one package. It is for use in microprocessor-based equipment using 68000, 8080 and 8086 families and supports polled or interrupt-driven procedures. Each channel may be programmed independently for operating mode or data format, operating speed being selected from 32 internally generated fixed bit rates, from a clock derived from the internal counter/timer or externally. Receiver and transmitter data are quadruple buffered in fifo and transmission from a remote device is stopped when the buffer is full. METL. Tel., 01844 278781; fax, 01844 278746.

Software

Windows NT driver development. Vireo Software's *Driver::Works* simplifies and automates NT device drivers using a C++ class library with *Driver::Wizard*, an automatic code generator, on-line documentation and working examples. The software is claimed to be a significant improvement over the Microsoft device driver kit and that drivers made using it will be compatible with Windows NT 4.0 and future versions, including Windows 97. Vireo Software Inc. Tel., 001 508 264 9200; fax, 001 508 264 9205. ■



Whatever next?

The good news is that artificial brains will be along by around 2035. But we may not need them – learning will have been superseded by transparent interfaces to smart computers about ten years previously.

Also, by 2025, robots will outnumber people in developed countries and the commercial production of antimatter will have begun. Between now and then, we can look forward to electronic cash displacing paper and coins by 2005, space tourism by 2002, 3D video conferencing and holographic displays by 2015, and full voice interaction with machines by 2007.

Thought control of computer games will be here next year, and wristwatch telephones should be in the shops any time now.

These are just a selection from a list of around 300 planned or expected developments collected from around the world by the techno-seers at BT's Martlesham Heath research laboratories, and published as the 1997 Technology Calendar.

This is no ordinary calendar, although it is designed so you could hang it on the wall. It sorts these breakthroughs into a dozen categories, including telecommunications, devices and machine interfaces, and lists them in order of anticipated first commercial application.

The list starts from this year and ends at 2040, by when global environmental management corporations will be inducing artificial precipitation and using nuclear fusion as a power source.

CDs on a roll?

The range of this predictive thinking is both wide and highly detailed. A slice through the future at the millennium, 2000, finds "evolving field-programmable gate arrays" and "3D very large scale integration with at least ten layers of devices" alongside "Leftel flat screens 100 times sharper than 1997 tvs but cheaper", and cds made on rolls 200 times faster at 3p a disk. Interactive vehicle highway systems will have arrived, and solar cells will be in common use for residential power supply.

The listings are necessarily brief, not to say cryptic at times. I feel I should know what "light detection sensitivity exceeding shot noise limit" is. By 2011, when it's due, I might well. Likewise TeraFLOPS and PetaFLOPS, both supercomputer speeds, the first due this year, the second in 2003.

On the other hand, "desktop fabrication units" and "active contact lenses" seem self-evident – or do they?

Biotechnology looks like making people obsolete. Before those artificial brains arrive, there will be artificial muscle and artificial pancreas, both next year, and artificial blood and ears in 2000. This will be followed by artificial heart, lungs, kidneys, liver, peripheral nerves and in 2030, fully-functional artificial eyes.

Artificial legs are not due until 2030. Before then, in 2020, artificial insects and small animals with artificial brains will have been developed. No doubt some of these will be programmed to bite robotic mail delivery automata, due about the same time – always assuming anything as old-fashioned as mail remains to be delivered.

And the bad news?

Not all the news is good. Only next year, it says, "viruses based on artificial intelligence will evolve and adapt," and by 2003, "various forms of electronic addiction will be a big problem."

The calendar also contains an addendum of various things, such as natural or human and social upheavals which could, at any time, throw progress off course. They range from an asteroid hitting earth or the melting of polar icecaps (oceans rise 100 feet) to mega-revolutions and terrorism, international financial collapse, the end of intergenerational solidarity or the collapse of the sperm count.

More ambiguous developments such as the growth of religious environmentalism and "new age attitudes" blossoming with the millennium, are also listed.

However, provided we survive these, and from about 2010, technology will give us the means to predict natural disasters, there is much to look forward to in the wonder-age of technology. Robotic pets in 2010 for instance, or on-line voting in 2007 and electronic referenda by 2010.

Only next year, we will be able to enjoy "many people sharing a visual virtual space..." I can hardly wait.

But it will not be until 2018 that the ultimate blessing of the electronic age – a video recorder capable of being programmed by adults – is delivered. ■

Tracking orbits

Martin Smith outlines the benefits of a satellite tracking controller that relies on a constantly evolving track model.

Precise tracking control on large communications satellite antennas is a serious business issue. Loss of traffic through controller failure on a transatlantic link can cost $1500 per minute and damage customer confidence.

Advanced controllers can also deliver useful savings by making it possible to use a low cost space segment on otherwise unsuitable satellites. Relaxation of north-south station keeping extends the operational life of a satellite, allowing it to be kept in service at marginal cost. However, the resulting inclined orbit requires active tracking to maintain workable signal levels.

Viewed from Earth, a satellite with 3.5° orbital inclination moves at up to 0.015° per minute. On a fixed Ku band antenna this would mean a drop of 4.0dB in the first five minutes and a further 12dB in the next five. This is operationally unacceptable.

First generation step-track controllers rely on moving the antenna to maximise a received beacon position. These are effective for geostationary satellites under good propagation conditions, but become unreliable when noise, rain fade or scintillation cause the beacon to fade.

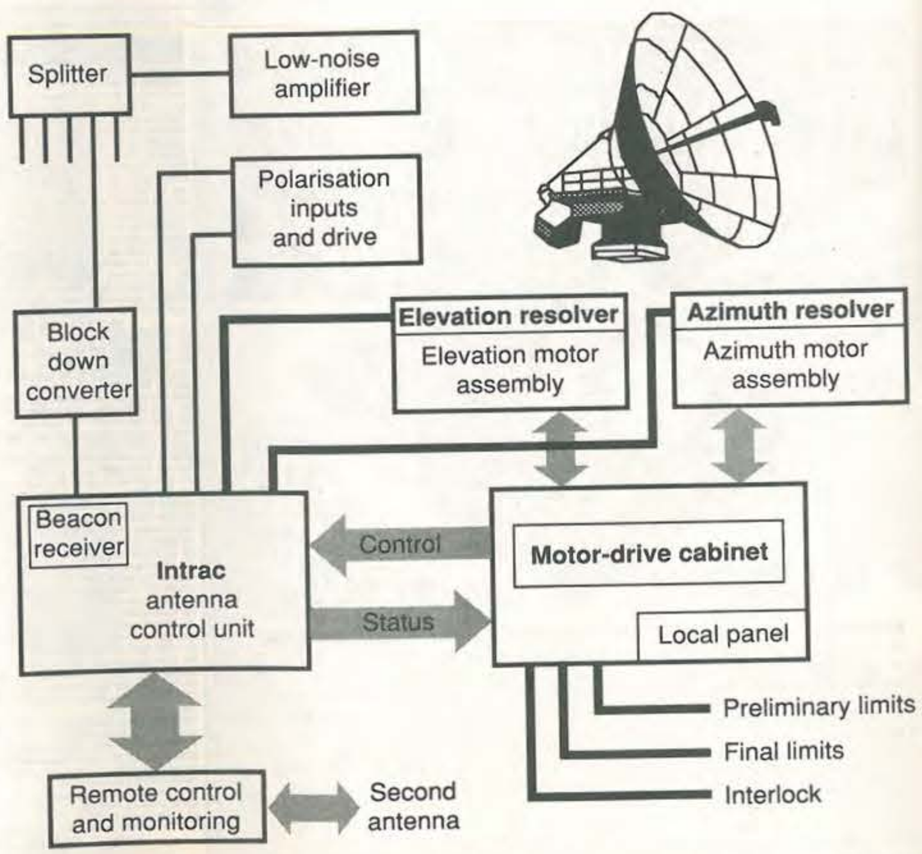
Memory track developments using stored data when beacon strength falls below a preset level are an improvement, but they cannot respond to wind effects or satellite station-keeping manoeuvres. The more accurate monopulse controllers process the rf signal directly but require elaborate and costly microwave equipment. Step-track controllers are often confused by the scintillation and fading which are particularly bad at elevation angles less than about 7°.

Dr Martin Smith is Director of INTRAC operations, Signal Processors Limited.

A new and more accurate system which steers the antenna in accordance with a mathematical model of the satellite orbit was developed on the initiative of the UK Post Office. In 1983 the software was licensed to Signal Processors and has been further developed as the Intrac, an acronym derived from intelligent tracking antenna control algorithm.

Modelling the satellite orbit

The concept is to create a multi-parameter model of the satellite track by an optimal esti-



A satellite antenna whose position is determined by data built up over a long time period has the ability to track a satellite accurately regardless of signal strength and, noise and wind force.

mation process. The estimation process combines a series of individual measurements of the satellite position. During the first 24 hours following switch-on, a short term model is used while controllers build a longer term model of the satellite track. This means that the antenna is always under closed-loop feedback control in accordance with a model evolving with time. This means that the system is almost unaffected by uncertainties in individual satellite position measurements. Accurate pointing is assured without any need for external data inputs.

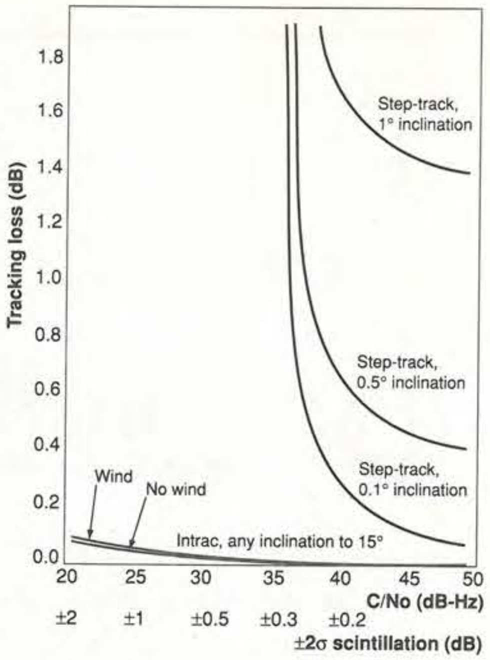
The current Intrac algorithm constructs its own fourteen-parameter model from step cycle measurements of the satellite position, normally at ten minute intervals. Resulting tracking accuracy is within a 0.05dB average for satellites with orbital inclinations to at least 10°. This corresponds to an average pointing accuracy better than 6.5% of the 3dB beam width. A relationship algorithm capable of tracking and correcting transients allows for windage, refraction and satellite station keeping manoeuvres.

Commercial advantages of accurate pointing can be calculated. A relatively simple controller may lose track five times a year and have an average mean time between failures of 50 000 hours – more than five years. This adds up to a loss of about 80 minutes of traffic a year, which may sound trivial.

A more sophisticated device, which can be expected to lose track less than once in two years and has a mean-time between failure of 120 000 hours, will not lose traffic for more than ten minutes a year.

The difference in traffic lost by the two systems over a ten year life will be more than 700 minutes. The value of transatlantic traffic on a big antenna can be $1500 per minute: thus, the revenue saved over ten years by using the more consistent and reliable controller will be over $1m.

Independence from external data inputs together with the use of high resolution transducers allows Intrac controllers to correct for wind deflections in the antenna and mechanical imperfections in its drives. It also makes it possible to maintain pointing accuracy even after the loss of the satellite tracking signal for several days. ■



Intrac performance compared with step-track against thermal noise, scintillation and orbit inclination.

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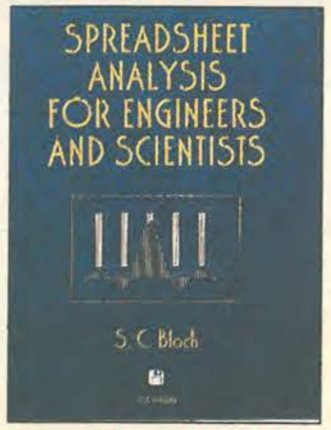

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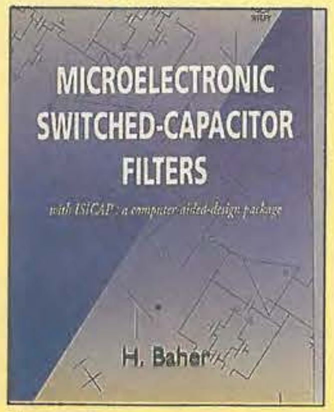

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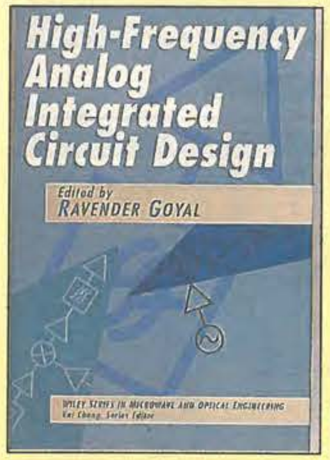

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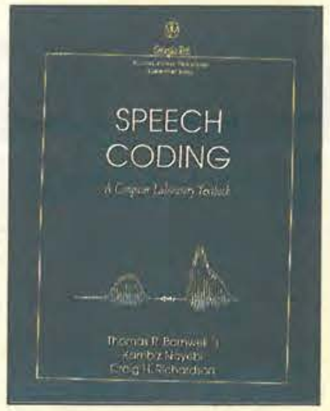

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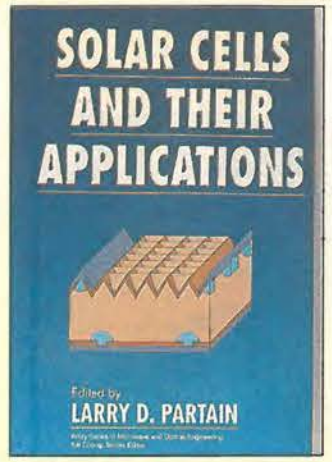

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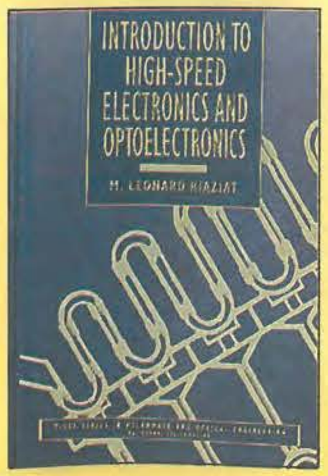

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LETTERS

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Not so perfect cds

Regarding the news story 'Doubts on digital recording quality' in the March issue, digitally mastered recording is unquestioned, and leads to the almost perfect replication of sound. However, in the 15 years I was involved in the development of cd players, saw a considerable decrease in quality.

● Compact discs are pressed by companies who are not aware about the parameters that have an influence on cd reproduction quality. Reading IEC 908 would be a good start.

● Reduced-quality optical systems decrease the optical signal-to-noise ratios, which results in a higher error rate. Although error correction has improved things, this can lead to an audible distortion.

● In the past, the digital and analogue circuits were in separate ICs. Today, digital filtering, the d-to-a converter and the first analogue amplifier are often combined within one IC. This results at least in a higher noise rate, increased distortion and much more crosstalk.

● And do not forget mechanical stability. The maximum allowed tracking error is expressed in ten-thousands of a millimetre. At this size, all component surfaces are rough and imperfect. Moving parts excite everything else – even fixed mounting plates.

The 'experts' should not blame the digital recording, but the decay in quality and/or know-how at compact disk and cd-player production plants.

Hr Vanderfeesten
Genk
Belgium

Light reflections

Professor David Koltick's theory of the electron as a dynamic, continuously changing object will certainly seem odd to those who are familiar with Establishment electronics (*EW*, May, p364).

In fact, the dynamic model of the electron was first proposed in *Wireless World* by Catt, Davidson and Walton in December 1979. They argued quite simply that a logic pulse travels at the velocity of light, and is not slowed down by the time needed to accelerate electrons. Thus, electrons must have an internal motion of light speed, so that their motion is merely deflected by the pulse.

Another argument is the velocity of light itself. Why is it constant regardless of the energy of the electrons emitting it? The answer is that the internal motions of the electron add up to light speed.

When an electron is moved along, at say half light velocity, then the internal speed (say electron spin plus orbital motion) is reduced from light speed to half that.

Nigel Cook
Addlestone
Surrey

Old glue news

It is a pity that you spent one and a half pages on a solution known for more than 30 years.

In 1966, we used a dual component bag from the manufacturer 3M. With a gentle pull in the middle of the bag the internal separation joint could be opened so that the upper and lower contents could be mixed without dirty hands or tools. This viscous mixture was used to fill isolation moulds at joints of high voltage cables.

Hr Vanderfeesten
Genk
Belgium

I wonder who supplied 3M? Ed.

Had I node beforehand

Readers tempted by limited-node circuit simulation software – specifically Spectrum Software's *Micro-Cap IV* evaluation version – may welcome this cautionary tale.

For anyone wishing to simulate small analogue circuits, *MCIV/EV* looks an attractive proposition. Within a limit of 25 nodes it offers the full modelling and simulation capabilities of *MCIV* and costs only $250. Having been impressed by Spectrum's free demonstration of *MCV*, I purchased a copy of *MCIV/EV* believing it would meet my immediate needs.

But the stated node limit is misleading. Despite the software itself identifying 25 or fewer nodes in a circuit, the analysis may nevertheless refuse to run because of nodes hidden within certain circuit components. A diode has one hidden node, for example; a bipolar transistor two. As a result, circuits you might reasonably expect to be analysable are not.

The *MCV* demonstration does not behave in this way. This – in addition to being a source of confusion – leads to the ludicrous situation wherein it is possible to analyse certain circuits

Simpler phase quadrature

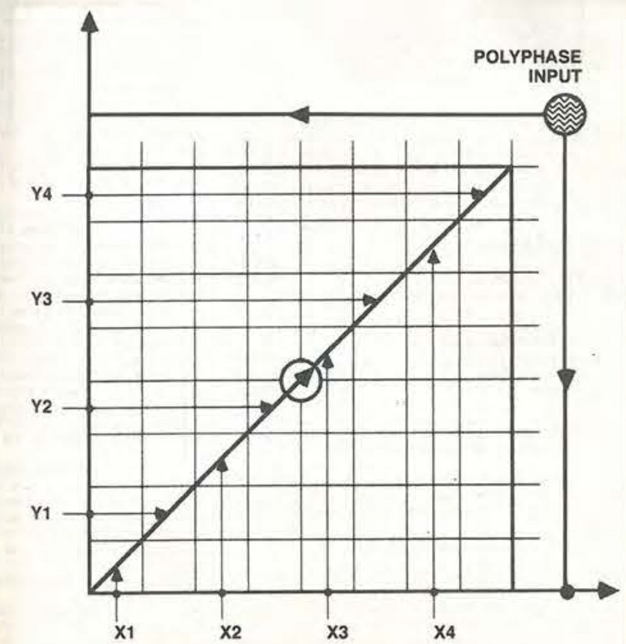
There is a much simpler procedure for designing phase quadrature circuity than that described by Professor Regalia in the June issue of *EW*. The underlying principle relies on modulo four arithmetic for expressing the geometrical quadrature of any rotary oscillation in which at least two cycles are completed in order to comply with the requirement for sampling at the Nyquist frequency.

The initial step is to construct a squire with one of its vertices located at the origin of a Cartesian graph system and two of its edges aligned over the X and Y axes, respectively. The four edges are then regarded as the ratio arms of a Wheatstone bridge and the principal diagonal from the origin as the nulling meter connection.

Differential quadrature phase shift over a restricted range of frequencies can then be calculated in terms of multibase (polylogarithmic) arithmetics by interpolative projection of an appropriate series of Y values among a second series of appropriate X values using the finite Fourier transform governed by modulo four arithmetic (see diagram).

The procedure can be extended to second order processing and automatic signing of complex signal patterns by rotating the initial square around the origin into the remaining three quadrants of the initial Cartesian graph system taken as reference phase, The methodology is essentially a generalisation of the concept of 'least squares' used in statistical practices.

B E P Clement
Clement Neuronic Systems
Crickhowell, Powys.



2 x 4-BIT TO 8-BIT DISCRETE FOURIER TRANSFORM (EASTINGS BEFORE NORTHINGS)

within its 10-node limit that will not run within the nominal 25 nodes offered by *MCIV/EV*.

Complaint to Spectrum about this elicited the grudging offer of a refund on the software's return – something which the company says is normally not available for the evaluation package. If honoured, that still leaves me out of pocket $85 for delivery, £25 for return carriage and – if I can't arrange a refund – £52 for duty and VAT: a total of £132.

I call that a notably poor investment, made all the more frustrating by the fact that Micro-Cap is otherwise such a delightful product to use.

Keith Howard
Twickenham

C here

As an amateur programmer, I was interested to see the C listing in the April 97 *EW*. I typed it in, as printed and it would not run. It seemed to have { } marks where it should have [ ]. Do { } marks take the place of [ ] on some versions of C ?

If not then this error exists in lines 5, 6, 22 and 23 as,

```
float mult "10"
value "24"
"ra"   "ma"
"r6"   "m6"
```

These should be, on my C version,

```
float mult [10]
value [24]
[ra]   [ma]
[r6]   [m6]
```

There is a missing minus sign in line 25 (the program thinks this line is on undeclared function when it is compiled). Original line 25 reads,

```
if (rl<=r2&&rc<=
rs+(rs*percent/100)&&rc
>rs(rs*percent/100)
```

It should read,

```
if (rl<=r2&&rc<=
rs+(rs*percent/100)&&rc
>rs-(rs*percent/100)
```

I have also added an extra line, `system ("cls")` between lines 8 and 9 to erase any garbage left on the screen from previous work etc.

Apart from the above comments, these small, useful programs should, in my view, be given more prominence.

R D Beck
Lydd
Kent

John replies:
Mr Beck is correct in his assumption that the quotes should be square brackets, and for this I can only offer him my sincere apologies. Although both the hard copy and the Word documents on disk supplied to the editorial office were correct, there was obviously a problem in conversion from Word to their DTP format.

The proof copy faxed to me prior to publication, I now see, was also incorrect and I should have picked this up. Omission of the minus sign in line 25 was my fault. The listing was typed into Word and this omission was not picked up – I will have to be more diligent in the future and ensure those sorts of errors are not repeated. With regard to the screen clearing command, each version of 'C' has it's own method of achieving a clear screen. As I wanted the listing to be portable I used only ANSI C standard commands.

I thank Mr Beck for taking the time to debug my listing. In appreciation I will be sending him a copy of the forthcoming Windows version of the full resistance calculation program.

IR proximity detector

Walter Gray tells us that in his proximity detector circuit on page 499 of the June issue, the *TIL100* diodes were shown upside down and the 100nF capacitor at the receiver output should have been drawn in parallel with the $100\mu F$ decoupler.

Error feedback error

In the same issue, in the Tandberg 3009A circuit on p. 478, the final drivers are powered by the 74V rails, not by the 64V rails. Ed Cherry's circuit was originally published as 'A high-quality audio power amplifier' in *Proc IREE*, Vol. 39, pp. 1-8, Jan/Feb 1978. The unmarked resistor to the left of Tr_{7a} is 3.3Ω, $470\mu F$ below this R is wrong polarity and 10mA on right-hand side should read 100mA. ■

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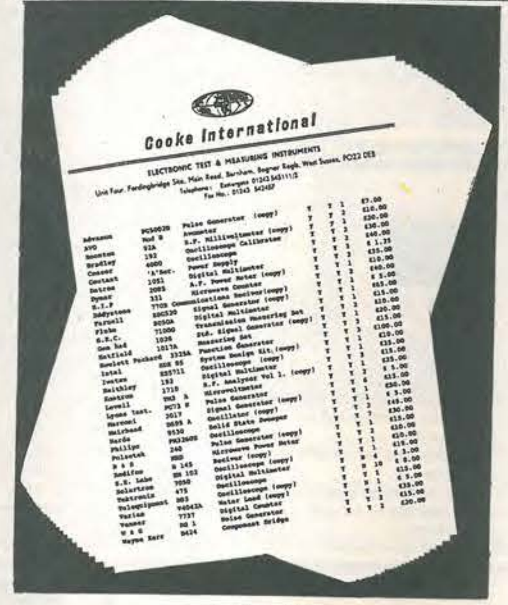

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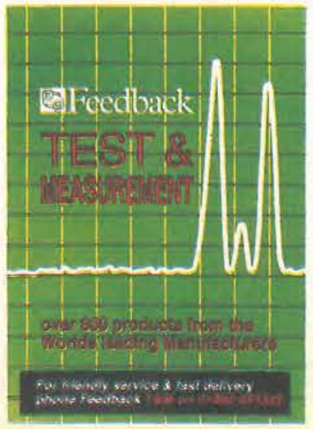

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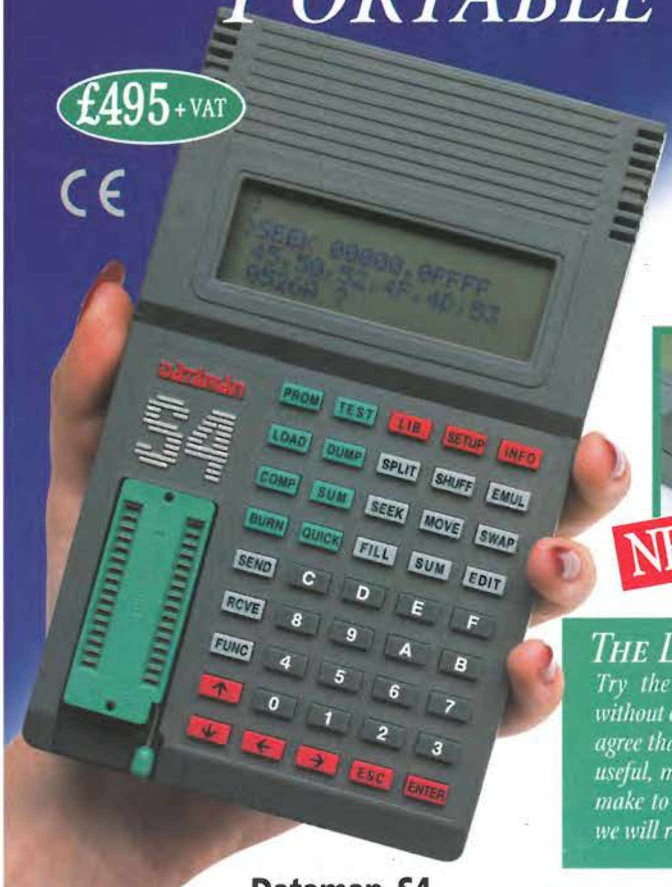

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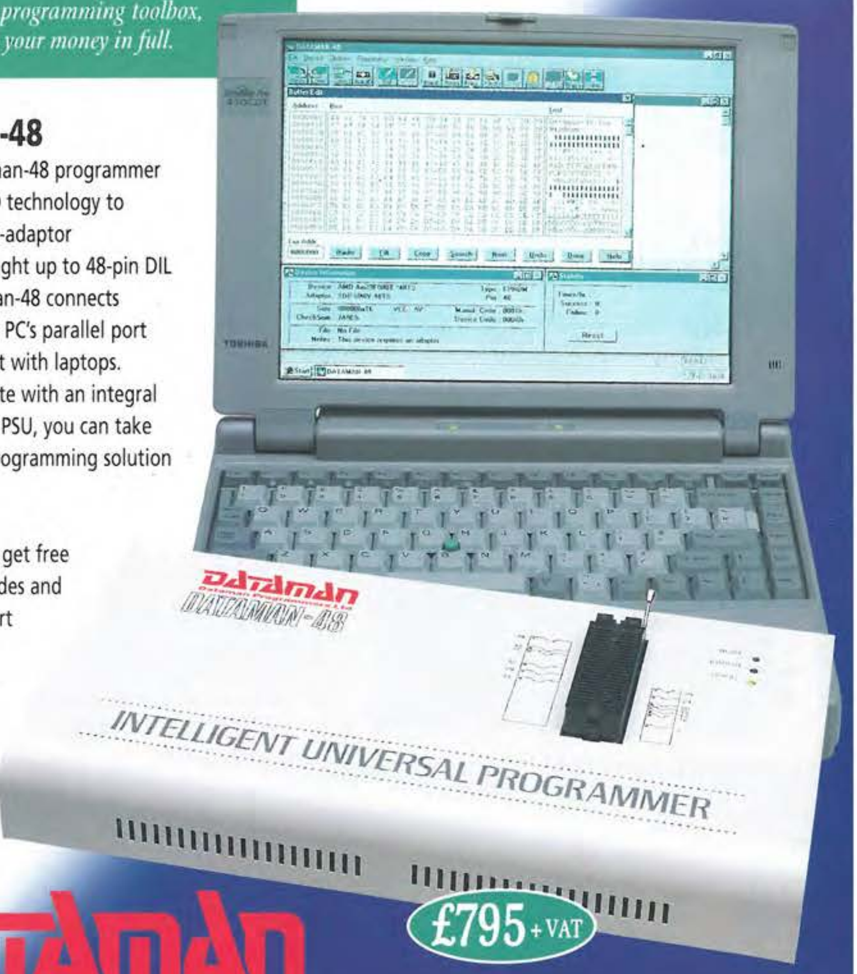

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