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TWISTED WORLD OF NON-LINEAR ELECTRONICS

It is just a small step to go from the resistance characteristics of a lightbulb to a state of chaos. Dan Aye's takes a look at the positive and negative aspects of non-linear components and circuit techniques.

RELIABLE PERFORMANCE AND A NEAT AUTOROUTER

As a PCB layout package, Layo may not immediately stick out from the crowd, but at its price, Martin Cummings finds it a reliable bet.

GRAVITY AND ELECTRIC FORCE FIND LINK IN BLACK HOLE

Is it just coincidence that the ratio of gravitational to electric force of the electron is so numerically close to Planck's time? D Di Mario hypothesises an electron with a black hole nucleus which could shed new light on the link between gravity and electricity.

NEURAL NETWORKS FIGHT CRIME AND DISEASE

Artificial neural networks can offer powerful processing systems, for instance in forensic science. But they must be used in the right way, says Tom Ivall.

COMMENT

Obscene call charges

UPDATE

Solid state gyroscopes for consumer applications; Diamonds are hip, Japan banks on memory at world chip show, High flying award, Court faces delay in Am486 chip, IEE and Engineering Council fall out over unity.

RESEARCH NOTES

Laser mends LCD displays, Feeding time at the black hole, More power to monolithic millimeters, Navigation by polarised light, Flower power?

LETTERS

Blumlein mystery, Microphone challenge, Power for the people, Working assumptions, Safe radiation, Quantum folly, Russian plea, Importance of history, No future.

DESIGN BRIEF

The long-tailed pair has proved a seminal influence in analogue circuit design since its first appearance. Ian Hickman explores the LTP's flexibility.

THE FISHTY TALE OF EARLY ELECTRICITY

Leonid N Kryzhanovsky shows how unravelling the mysteries of the electric fish prepared the ground for development of the battery

THE GPS MESSAGE ON THE HARDWARE PLATFORM

Data content of the GPS is complex because it carries corrections ranging from relative movement to relativity. But it is also subtle because it was originally designed to be decoded without powerful computers. Philip Mattos examines the connection between software and hardware.

PROFESSIONAL SERVICES OFFER LOW POWER RADIO LINKS

The DTI no longer requires licensing for certain types of low power radio links, and so wireless data transmission has never been easier. Read Ian Hickman to unravel the technology then save 50% on the price of the transmitter/receiver modules described in the article.

HEAT TURNED UP ON SUPERCONDUCTOR CABLES

Power transmission cables with no losses has come a step closer with development of new superconducting materials. Andy Wright reports.

SELF-CALIBRATING NOISE SOURCE USING SILICON

Semiconductor noise sources, needing calibration by the manufacturer, are needlessly expensive. T H O'Dell describes a novel way round the calibration problem.

TROUBLESHOOTING ANALOG CIRCUITS

In the first of a series of extracts from his book Troubleshooting Analog Circuits, Robert Pease looks at the diode and shows how to handle its imperfections.

CIRCUIT IDEAS

Amplifier clip detector, Current-to-frequency converter, Schmitt-trigger VCO, Programmable PWM, Swept VCO

NEW PRODUCTS

EW + WW's round up of all that's new in electronics and engineering software.

APPLICATIONS

Fuzzy logic de-fuzzed, DC-to-DC converter transistors, Stereo D-to-A converter.

In next month's issue: The thought of working with DSP frightens many people. We present a design for a simple PC add-on card which allows experiments with TMS320C10 code.

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COMMENT

Obscene call charges?

It's time for the Government to come clean over its plans for introducing true competition into the UK telephone market.

The Government’s wish to protect the lucrative international telephone businesses of BT and Mercury Communications is denying most domestic subscribers the chance of buying their telephone service from someone other than British Telecom.

The proposition is simple. Overseas traffic is lucrative. From a technical point of view it has never been easier to go into business as an international carrier. It requires little more than a modest satellite link and a switching centre to hook into the UK’s existing trunk network. The centre intercepts 010 numbers and routes them automatically through Intelsat. The phone system in the receiving country does the rest. The equipment required fits comfortably into the average suburban house. A condition of granting the operators’ licence would be that the new carriers make substantial and much needed investment in UK local telephone networks. The profit from international traffic should fund competition for the wire that comes through your front door.

There are already signs that US operators are prepared to invest in local telephone networks through their interest in UK cable television companies. But without international licences the biggest US telephone operators are discouraged from investing billions of dollars in Britain. On paper the UK may have the most liberal telecommunications market in Europe but the benefits to private subscribers have been limited to cosmetic niceties. Pictures on phonecards and award-winning television adverts may give the consumer a warm feeling towards BT. But most of us have not seen reduced telephone bills or improved the service as a result of direct competition. For most BT is the only choice. Two years after the White Paper supposedly opened the UK market to anyone with the money to invest, BT’s virtual monopoly over Britain’s 24m telephone lines is still secure.

One of the largest telephone operators in the US has waited a year for the Government to give the go ahead for its plans to invest hundreds of millions of pounds in a British domestic network. The problem is it wants to carry its own international calls.

This application is being viewed as a test of the Government’s commitment to competition by many potential investors. Government seems reluctant to risk the wrath of BT and Mercury which retain duopoly control of international telephone traffic. This seems perverse given the Government’s loudly stated determination to break that same duopoly for all other UK telephone services.

Only a cynic would suggest that the Government is concerned over the effect on BT’s share price before it has the chance to off-load its remaining 22% holding this year. Any threat to international call revenues, which account for 14% of BT’s business and an even larger share of its profits, would alarm the City, a body not without its quota of cynics.

It must be remembered that no other country is even considering foreign ownership of its international telephone carriers and the Government is wise to tread carefully. But seeking reciprocal agreements in the US may not be realistic and could lead to serious delay.

One thing is certain. Real service improvements for the domestic subscriber will not happen without effective competition to BT. New domestic services cannot be funded without the high profit revenues from international traffic.

Surely it is not beyond the wit of President Heseltine at the DTI to come up with a compromise which offers the carrot of international business with the condition of substantial investment in UK telephone networks.

British Telecom has enjoyed the good life for years. It is about time that real competition provides benefits for all of Britain’s 2 million telephone users.

Richard Wilson.
Richard is Communications Editor of Electronics Weekly.
Better deal needed from memory cards

Public acceptance of memory card technology will stay low until a universal filing system transparent to the end user is agreed, according to a report from manufacturer Fujitsu.

The report says that "compatibility between cards still needs to be addressed as the card software and with it the formatting and filing system can cause problems when using different manufacturers' machines."

Japan is the largest market for the cards. According to research by SRI International, in 1991 the total Japanese market was 1.1 million cards which is expected to grow to 64 million by 1995.

ROM cards are estimated to have 68% of the market which it is predicted will slip to less than 30% by 1995. These are used for storing software for use with card only machines.

The second largest group is for SRAM cards with 17%. This sector is growing fast and is expected to have the largest share at 35% by 1995.

But the big expansion will be seen in Flash cards - from 3% in 1991 to nearly 22% in 1995.

The Fujitsu report said: "For the Japanese model to be repeated across the world, it is essential that the industry and the end user is made aware of the advantages of this memory media."

The growth should be boosted by the development of a wide range of non-memory cards including units for modem, lan, and ISDN applications.

Fujitsu means that while makers of PCs, laptops, and palmtops are designing PCMCIA sockets in their products, these are normally an optional extra and not built-in as standard.

A wide range of new card products are expected in the autumn including DRAM and SRAM cards which can be used like floppy disks for storing data which can easily be read and overwritten.

RF transistor develops 600W

Motorola has produced a continuous duty 600W RF power transistor operating up to 80MHz.

The MRF157 device has been designed with silicon nitride passivation, source ballasting and integral gate resistors.

Supply voltage is 50V and typical characteristics include a gain of more than 25dB at 30MHz, drain efficiency of 45%, and a third order IMD at rated output power of -25dB.

Other specifications include $V_{ds}$ of 125V, $V_{gs}$ of 220V, and a continuous drain current of 60A.

The package is designed for conduction cooling. If a copper heatsink is not used, Motorola recommends a copper head spreader between the device mounting surfaces and the main heatsink. Samples and small quantities are available from stock at about $500 each.

Applications for the device include SSB transmitters, amplifiers used with magnetic resonance imaging equipment, sputtering equipment, and amplifiers operating at up to 80MHz.

Court forces delay in Am486 chip

There will be a six month delay in the introduction of AMD’s Am486 microprocessors following a federal court decision last year that a copyright licence between AMD and Intel does not extend to microcode in Intel microprocessors.

But Jerry Sanders, AMD’s chair, put on a brave face. He said: “While we are bitterly disappointed at the ruling, it will have no unanticipated impact on AMD. As a prudent company, we had a contingency plan. Development of an independently derived microcode for the Am486 family has been under way for some time.”

His view on the ruling though was clear when he added: “No verdict or ruling can change the underlying truth. In 1976 I negotiated in good faith and AMD paid a substantial sum for the rights that AMD is now being denied. There is no acceptable alternative for us than to continue to fight for justice.”

Walker gets honorary degree

Electroacoustics and hi-fi specialist Peter Walker has received an honorary Doctor of Science degree from Keele University.

Walker started his own business at 19 years old which became known for the Quad range of amplifier and loudspeaker designs. In 1954 he produced the world’s first full-range electroacoustic loudspeaker.

He received an OBE for his contribution to the audio industry in 1990.
Japan banks on memory at world chip show

Once again Japanese memory technology looks set to dominate this February's IEEE International Solid State Circuits Conference in San Francisco.

This year is the 40th anniversary of the conference which has gained the reputation of being the main forum for highlighting practical semiconductor developments. Only papers based on working silicon are accepted for presentation at the conference.

Among the highlights are papers on 256Mbit drams from Hitachi and NEC, and a fast 256Kbit bicmos ram also from Hitachi. The NEC dram uses a multi-divided array structure and has an access time of 70ns. It is made using 0.25um cmos technology with a finely divided 1/1024 array access activation architecture.

The same cmos technology is used for Hitachi's dram which has an access time of 70ns. Standby current is 26uA at 1.5V using sub-threshold current limiting and sub-array replacement to repair wordline-to-bitline shorts.

Hitachi's new static ram has an access time of just 1.5ns and comprises two 128K-bit ram blocks configurable from 2K by 64-bit to 32K by 4-bit from eight modules. It uses 0.5um technology. Despite Japan's high standing in the memory arena, as usual the USA is the most predominant with more than 60 of the less than 110 papers being presented. Japan has less than half the number, the rest being made up with a smattering from Europe, Canada, and the rest of the world.

One of the US' most exciting developments appears in a paper from Michigan University on a 160,000 transistor GaAs microprocessor. This 200MHz 32-bit rise chip uses a 2V 1um GaAs DCl/F process and dissipates 24W.

The growth in high volume radio phone systems has driven the development of new radio architectures which largely eliminate conventional IF stages and the consequent trimming adjustments. They use quadrature local oscillator signals running at signal frequency feeding a four-quadrant transistor multiplier core. Typical of this is a device from the USA. It features a 2.5GHz silicon bipolar image-reject front end from National Semiconductor using 0.8um bicmos technology. A Spanish paper from Telefonia Española in the same session describes a 0.7 to 3GHz GaAs QPSK/QAM direct modulator.

The Fraunhofer Institute for Applied Solid-State Physics in Frising, Germany, is presenting a paper on an 18 to 34GHz dynamic frequency divider based on 0.2um AlGaAs/GaAs/AlGaAs quantum well transistors. It consists of a two-ring oscillator configuration with NiCr thin-film resistors, MIM capacitors, and two-layer wiring.

In the image sensors and displays section, a joint paper from GTC and NEC gives details of a polysilicon TFT detect-tolerant scanner. The circuit is claimed to be immune to open and short defects without circuit repair. It has been developed for active-matrix liquid crystal displays.

Silicon flow valve uses IC technology

A light weight silicon microvalve looks set to help drug dispensing and ventilator and respirator control in hospitals.

The device is made by IC Sensors and can proportionally control gases and fluids.

Henry Schuster, managing director of IC Sensors' Eurosensor division, said: "It is not just open and shut. It can be used as a proportional controller. This lends itself to medical dispensing for say a drug in a patient or automatic dispensers in hospitals."

It weighs just 0.3g and is designed to replace larger solenoid valves weighing upwards of 15g.

Made using micro-machining technology, each valve consists of a centrally bossed silicon diaphragm mated to an etched silicon valve body. A thin metal film is deposited on the diaphragm to form the bimetallic actuator.

By adjusting the electrical power dissipated within the resistors implanted in the diaphragm - and thus the temperature of the actuator - the thermal expansion difference between silicon and metal results in the controlled displacement of the central boss away from the valve seat.

Schuster said: "There are people who don't want a mechanical or electromagnetic device for switching gases or air or whatever. They want a device in which nothing moves. There are no plungers or inductances. It is purely a piece of silicon that opens or closes an orifice."

The devices cost £55 each, but this comes down to £28 for orders more than 5000.

Other medical applications include controlling the pressure on patients lungs when in a ventilator. It can also be used for in-throat respirators to gently open and close the air flow.
Solid state gyros from piezo spin-off

Mechanical gyroscopes based on the principle of rapidly spinning top have served for many years as sensors in inertial navigation equipment on board aircraft and ships. These naturally require precise machining. If gyros could be produced at consumer prices there are many applications which would readily use them. For instance low cost inertial navigation for cars and light aircraft, stabiliser systems, aids for blind people.

Optical gyros record angular velocity by measuring the relative phase of standing waves of light set up in a ring of optical fibre. There are no moving parts but this technique remains expensive. However, a new class of gyroscope based on piezoelectric vibration promises a combination of price and performance for consumer applications.

The Japanese company Murata has developed a viable gyro system which sells for just £40 in high volume. It demonstrated the thumb-sized device acting as a stabiliser on a model radio-controlled motorcycle at last November’s Electronica show. The gyro allowed the model to remain upright at impossibly slow speeds.

The vibrating piezoelectric gyro is a true angular velocity sensor. It makes use of the Coriolis effect, a force which develops at right angles to the direction of moving object subjected to a rotation. This is the same force which determines the direction of water down a plug hole, and that standing into wind in the northern hemisphere tells you with certainly that you have the centre of depression to your right.

Piezoelectric gyroscopes are essentially simple structures. A number of electrodes fitted radially to a typically cylindrical or Toblerone shaped bar of piezoelectric ceramic material are made part of an oscillator circuit working at the resonant frequency of the piezo structure. The electrical signals developed across the transducer facets exhibit a fixed phase relationship with each other unless disturbed by some external force. When the bar is subjected to rotation, the Coriolis force comes into play causing the phase relationships to change. The difference relates directly to the amplitude of rotational velocity.

Practical structures and circuits tend to use three, equally spaced electrode pairs fixed to the piezo bar with one electrode of each pair connected to ground. The signal electrode from each of two pairs feeds a limiting differential amplifier which produces an output which is proportional to the Coriolis force and thus to the angular rate of rotation.

The measurement circuit compares output from the differential amplifier with the drive signal applied to the bar. Phase variation relates directly to turning forces applied to the bar as the Coriolis force modifies the vibrational pattern of the ceramic crystal.

Typical sensitivity for Murata’s Gyrostar is about 30mV/degree/second with a linearity of 0.1% up to the maximum rotational rate of 90°sec⁻¹. Frank Ogden

IEEE and Engineering Council fall out over unity

The Engineering Council and the IEE are at loggerheads over the Fairclough initiative for a new single body for the engineering profession.

Despite giving a cautious welcome to the proposals, the two bodies disagree over the way it should operate.

The Engineering Council believes that the institutions should be subordinate to the new body rather than having a relationship based on a partnership as suggested in the proposal. It statement said: “The new body must necessarily be above, not on a par with, the institutions.”

However, the IEE believes the tasks of judging applicants and awarding discipline specific titles for qualifications, performance and conduct should be the role of the institutions as should the process of accreditation.

And the IEE made clear in a statement that “Registration should be limited to engineers who are members of appropriate institutions.”

The Engineering Council though considers it essential that membership of the new body should include outside members. Otherwise it believes the new body’s council would become “the creature of the institutions and would sideline the interests of industry, education, and the desire of those who are on the Council’s register to have some form of representation.”

While the IEE appears to approve of the idea of a partnership, the statement from the Engineering Council says: “Such a body would need to have direct control of its subordinate organisation and this therefore will necessarily exclude concepts of equal partnership.”
BARGAINS—Many New Ones This Month

THIS MONTH'S SNIP is a 250 Watt Triode Transformer which has 24 good inputs and 3 secondary circuits: 230v, 115v and 6v but does not have a fuse, and quite what you want it is very easy to add an extra winding, 4 lamps or subjects 1. It can also be noise isolated. Price only £10 but it’s necessary to add £2 carriage if not collecting. Order Ref. 10P97.


FM CORDLESS RADIO MICRO, hand-held, battery-operated professional model, has usual shaped body and head and is tunable to transmit and be picked up by an FM band of radio. Yours for only £4, Order Ref. 892.

FOUR MORE SPEAKERS. Order Ref. 1.5P11. This is a Japanese-made 6⅛”, 8 ohm, rated at 12W max. This is a very fine reproducer. The makers are SANSY. Yours for £1.50 Order Ref. 908. Order Ref. 907 is another Far East-made 6⅛”, 40 ohm, max speaker. Very nicely made, using Japanese Hitachi tools and components, only £1. Order Ref. 896 is 6⅛”, 10W, exceptionally good sounder and yours for only £1. Order Ref. 909. Order Ref. 906 speaker rated at 5W but its unusual feature is that is has a built-in tweeter. Still only £1.

MULTI-CORE CABLES use at 8A 230V core so suitable for disco and other high-current circuits. Easily solderable welding versions are also available. Price £3 per 30m, 16-core, 50p per metre, 16-core, 80p per metre, 25-core, 10W, 60p per metre and 100-core, 80p per metre. YOU CAN STAND ON IT! Made to house GPO telephone equipment, this box extends to 3m, £1, Order Ref. 846, 2-core, 13A, extends to 1m, £1 each. Order Ref. 845. The other one is 2⅛” x 2¼” x 1⅜” deep, 2 for £1, Order Ref. 565. BUILD YOUR OWN NIGHT LIGHT, battery charger or any other gadget that you want to enclose in a plastic case and be able to plug into a 13A socket. We have two designs, one 2⅛” x 2¼” x 1⅛” deep, £1 each. Order Ref. 945. The other one is 2⅛” x 2¼” x 1⅔” deep, 2 for £1, Order Ref. 565. SAFETY LEADS curly so they can’t contract but don’t hang down. Complete with a 10A fuse being 2-core, 5A, extends to 3m, £1, Order Ref. 846, 2-core, 13A, extends to 1m, £1 each. Order Ref. 847, 3-core, 13A, extends down to 3m, £2 each. Order Ref. 2P590.

POWER SUPPLY WITH EXTRAS main inputs is fused and filtered and the 12V output is voltage regulated. Intended for high-class equipment, this is mounted on a PCB and also motor power. One is 2½” x 1¼” x 1⅛” deep but easily removed, are 2 12V relays and a Piczo sounder. £3. Order Ref. 3P898.

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12V SOLID STATE BARGAIN has good ‘p’ pull or could push it modified, size approximate 1½” long by 1⅛” square, £1. Order Ref. 232.

15W 8-OHM SPEAKER & 3 WATT SPEAKER is made for a discontinued high-quality music centre, gives rich top, and only £4 per pair. Order Ref. 4P7.

3V SOLAR PANEL price £3. Order Ref. 919.

SOLAR ENERGY EDUCATION KITS an ideal present for electronics students. It shows how to make solar cells and electrical circuits, how to increase the voltage current, how to use solar power to work a radio, and how to charge nicad batteries. The kit comprises 8 solar cells, one solar motor, fan blades to fit motor and metal frame to hold it to complete a free-standing electric fan. A really well-written, instruction manual makes this a lovely little present. Price £8. Order Ref. 1 SP9.

10-1MA FULL VISION PANEL METER 2½” square, scaled to 0-2.5A, made easily removable for re-writing. £1 each. Order Ref. 756.

PROJECT BOX a first-class, Japanese two-part mounding size 2½” x 2½” x 2½” deep. Price £3. order Ref. 904.

This is nicely finished and very substantial. You get 2 for £1, Order Ref. 876. 12V 2A MAINS TRANSFORMER upright mounting with extra clamp. Price £1.50. Order Ref. 1 P91. £1/2 per 30-core, £5 per 30-core, 30p per metre, 16-core, 50p per metre, 16-core, 80p per metre, 25-core, 1W, 50p per metre and 100-core, 80p per metre. ORDER OF 10 stands will be £2.50 each. Order Ref. 875.

AM/FM RADIO CHASSIS with separate LCD module to display time and set of stations. This is complete with loudspeaker but the eyes are £6. Order Ref. 3P87.

2, 3 AND 4-WAY TERMINAL BLOCKS the usual grub screw types. Price £1.50 per block. Order Ref. 7.5P/4.

12/24V DC SOLID STATE CONSTRUCTION so that it will push or pull, plunger is a 20 WATT POWER RELAY and is fully adjustable but will work well at 12V, and, of course, with any intermediate voltage. Good value. £4. Order Ref. 10P89.

MILLIMETRE RANGE MULTI-METER 150V DC, 1000V AC. Ideal for testing and guaranteed OK, probably cost at least £50 each, yours for £4, Order Ref. 10P97.

PROJECTS TO MAKE WITH SOLAR LIGHTS. Kit 1 is a free-standing electric fan. Kit 2 is a 2½” x 2½” x 2½” deep solar panel complete with solar motor, £8, Order Ref. 69P1.

PROJECTS TO MAKE WITH SOLAR LIGHTS. Kit 3 is a solar motor £3, Order Ref. 5P189.

A ULTRASONIC BARGAIN, a two-channel 10W 8-Ohm speaker with a tone control, £6, Order Ref. 5P202.

An ultrasensitive speaker with a tone control, £6. Order Ref. 69P1.

120 WATT TRANSFORMER 230V in and 230V out. 150watt upright mounting, £7.50, Order Ref. 7.5P/4.

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CIRCLE NO. 106 ON REPLY CARD
Laser mends LCD displays

A team at the GEC-Marconi Hirst Research Centre at Wembley has developed an ingenious laser technique for repairing manufacturing defects in the drive circuitry integrated onto the glass substrate of advanced LCD displays.

In their latest paper (Electronics Letters Vol 28, No 24) the GEC-Marconi team points out that as displays get larger, the chances of process-induced defects also become greater with a corresponding reduction in manufacturing yield. So any method repairing defects is likely to become more important as time goes on.

The idea of devices that can be repaired is not in itself new, but there are considerable problems when the operation involves anything more than burning out shorts and unwanted links — especially where doped polysilicon is used for interconnects and where the device involves liquid crystals on a glass substrate.

GEC-Marconi has not only developed ways of cutting unwanted connections on the micron scale, it has also demonstrated its ability to join open-circuit links, even in fully assembled displays filled with liquid crystals.

To implement this technique, the display has to have redundant or spare circuitry on the substrate. Normally this is non-functional and adds little or nothing to costs. But if an active circuit element proves faulty on test, the system will allow a manufacturer to cut out the faulty part and micro-weld in the spare circuitry. The unit should then behave to its full design specification.

Cutting links on the micro-scale presents few problems; a laser can easily be focused on the link to blast away unwanted metal. But welding together open-circuits is much more difficult, especially where the intended joint is not between two metal parts, but between metal and polysilicon.

The GEC-Marconi team has achieved all these objectives using a Nd:Yag infra-red laser directed by means of a bench microscope. A beam-splitting device and a separate low-power visible-light laser to align the system is included, and using this arrangement, the cutting/welding beam can be aligned to within 2μm of its intended target.

Results have been impressive — especially with welded joints — all of which have proved reliable, even when carrying currents above their normal operational values. The figures show what happens when the laser punches metal through the insulating layer. The electrical connection is believed to take place along the wall of the hole.

As well as repairing faults on test substrates, the new technique has been successfully tested on fully fabricated displays containing liquid crystals. More laser power is necessary to achieve a successful weld, but apart from a few transient bubbles in the liquid crystal, results are identical. Faulty displays — with up to 65% of the display area blank — have been restored to full working order.

The GEC-Marconi team says that the technique lends itself well to automation and is likely to lead to a vast improvement in manufacturing yield.

Films before and after welding.

Photomicrograph of two (part) stages of LCD column driver welds (W) and cuts (C) with the SEM of a successful weld showing breakthrough.
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- battery powered. Housed in polished wood carrying box - tested - £100-£200-£250. 1, 2 or 3.
Precision Aneroid barometers- 900-1050Mb - mechanical digit readout with electronic indicator
SE Lab Eight Four - FM 4 Channel recorder - £200.
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TM506 - 7904 - 7834 -7104.
Tektronix 491 spectrum analyser - 1.5GHz-40GHz - as new - £1000 or 10Mc/s 40GHz.
AC L Field Intensity meter receiver type SR - 209 - 6. Plugs - ins from 5Mc/s to AGHz - P.O.R.
Infra -red Binoculars in fibre - glass carrying case - tested - £100. Infra -red AFV sights £100.
Feeding time at the black hole

In spite of the bad press that surrounded the Hubble space telescope and its design flaws, lots of good science is going on up there in orbit. Investigators using the wide field/planetary camera have recently reported the best views yet of the disc of material that is being pulled into the jaws of a suspected black hole. A black hole is a still-theoretical object which forms after a massive star collapses. The matter becomes so densely compacted that its powerful gravitational pull traps all matter that comes near to it. Not even light can escape, which explains why no-one has ever seen a black hole.

The disc in the picture, presumed to be the feedstuff of a black hole, is at the core of a galaxy in the Virgo Cluster 45 million light years from Earth. According to Dr Walter Jaffe of the Leiden Observatory in the Netherlands, one of the investigators, the nucleus of this system is probably the home of a black hole with a mass 10 million times that of our Sun. The system, described as an “active galaxy”, emits especially strong radiation which provides evidence that it harbours a powerful energy source.

The photos show a comparison between the results from the Hubble and the best ground based optical or radio images.

More power to monolithic millimetries

Semiconductor development is mainly a process of steady improvement, punctuated occasionally by radical new technologies. But continuing progress in certain key areas, while rarely headline-grabbing, is currently spawning impressive new performance specifications.

Take for example the recent announcement (Electronics Letters Vol 28 No 23) of a monolithic millimetre-wave IC capable of 14.2dB power gain at 47GHz. That in itself is impressive, but this four-stage device, developed at Comsat Laboratories and Hercules Defense Electronics Systems Inc in the US, is a power chip with a linear output of 165mW. Its developers claim the chip has the highest power gain and complexity of any single MMIC at U-band frequencies.

Designed using the Touchstone microwave circuit analysis program, the 5mm chip incorporates integrated RC components, ensuring unconditional stability down to a few MHz.

Fabrication involves growing layers by molecular beam epitaxy (MBE) and then isolating components using optical lithography and direct-write electron beams. Evaluation of the chip’s performance involved the development of a special input/output coupling system using a ridged waveguide transition with less than 0.2dB insertion loss over the frequency range 40-48GHz.

The authors of the paper say the already impressive power output can be increased further by using several of these devices in conjunction with low-loss off-chip power combiner/dividers.
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**CIRCLE NO. 109 ON REPLY CARD**
Navigation by polarised light

Polarisation is a familiar enough concept to those who design and install RF antenna systems. But Lawrence Wolff, a computer scientist at Johns Hopkins University in Baltimore, is on the verge of developing a polarisation-based navigation system.

All electromagnetic radiation can be polarised or made to vibrate in a preferred plane. Light, like radio energy, can also become polarised when its waves are generated or filtered, so as to assume a definite angular orientation. Normally we generate or filtered, so as to assume a become polarised when its waves are generated or filtered, so as to assume a definite angular orientation. Normally we humans can not tell whether light is polarised or not — though legend has it that the ancient Vikings had the ability to navigate at sea by detecting the polarisation of light from the sky.

Today those variations in polarisation are mainly exploited by photographers who use special filters to make the sky look a deeper shade of blue or to eliminate reflections from glass or water. They work because when randomly polarised light is refracted or reflected it becomes markedly polarised, and so can be attenuated by a filter with opposite polarisation.

Wolff realised that this normally-invisible information could be decoded and used to advantage by computer vision systems. He reasoned that if polarisation information could help bees and fish — and arguably Vikings — to navigate, then the same information could help an artificial vision system to make sense of confusing or ambiguous data from a video camera. Video cameras, like human eyes, are normally polarisation-insensitive.

Wolff’s research is backed by the Defense Advanced Research Projects Agency (Darpa) and covers a patent application for a polarisation-sensitive camera sensor. He sees a potential application of the principle in development of a vision system for Darpa’s unmanned ground vehicle programme. “The system would enable such a vehicle to navigate terrain, avoiding such pitfalls as going off cliffs, driving into lakes or running over people. It could also help prevent robots used in science and industry from running into glass doors or other transparent objects.”

Ultimately, it is thought that polarised vision systems might be used to navigate space rovers on planets that have no magnetic field.

Laboratory results show that, as well as preventing vehicles falling into lakes, the vision system can enable computers to distinguish between visually similar materials that have different polarisation characteristics. Metals can easily be distinguished from non-metals and even substances with varying electrical conductivities.

Wolff’s camera represents a new class of image sensor in which there is no longer the need to rotate polarising filters mechanically in front of a lens. The system makes use of liquid crystals to steer or rotate the plane of polarisation of the incoming light so that it can subsequently be analysed by a fixed polarisation filter. Four-dimensional computer vision, it seems, is just around the corner.

Flower power?

Animals, including ourselves, operate essentially by electricity. Action potentials — pulses of up to 70mV — indicate that a message has flashed along one of the neurons that make up the nervous system. But though electrical transmission of biological messages is universal throughout the animal world, few scientists have ever suggested that plants might be wired up in a similar way.

Now, strong evidence for this comes now in a paper (Nature Vol 360 No 6399) published by a team from the Universities of East Anglia and Leeds and the Horticulture and Food Research Institute of New Zealand.

Botanists know that plants have a crude sort of communications system that allows one part — usually the growing tip — to send a message to another part telling it to respond to gravity or light etc. The transmitter in this case is a chemical that diffuses from one area of the structure to another. But there is one intriguing plant reflex that has remained a mystery because no-one has ever discovered a chemical agent that operates it.

Imagine a small tomato seedling quietly minding its own business, when along comes a gang of hungry caterpillars, munching away at the top leaf. The assault does not go unnoticed and a message is sent to other leaves telling them to manufacture a nasty-tasting chemical: when the caterpillars move on to pastures new they end up with severe indigestion. Simple negative feedback! It’s also a form of self-defence that occurs quite widely in the plant kingdom.

But how does leaf A communicate with leaf B, telling it to retaliate? Dr David Wildon and his colleagues had a hunch that this communication might not be chemical but electrical, as in animals. Because of its unorthodoxy, they had to go to extraordinary lengths to make their case.

They wired up a tomato seedling with electrodes and wounded the leaf seed. Some 30s later they observed a pronounced electrical peak that was shown to travel along structures called plasmodesmata — tiny channels with properties remarkably like the gap junctions of human nerve cells.

To prove the voltage spikes were not merely some incidental effect, the scientists chilled part of the plant’s leaf stem to prevent the transmission of any coincident chemical signals. There was virtually no difference, suggesting strongly that the prime means of communication was indeed electrical.

So what does this all mean? To begin with, the finding does lend some slight credibility to occasional reports of plants being used as transducers to predict earthquakes or other traumatic events. Plants might just possibly respond to premonitory movements that humans can not detect directly.

But more relevant to most of us is the risk of someone setting up a society for the prevention of cruelty to plants. Taking a leaf from the animal welfare organisations, they might well home in on the innocent gardener pruning a much loved rose. If you’re at all worried, Dr David Wildon has some helpful advice from his research: use a sharp pair of secateurs. It appears that a clean cut to a leaf doesn’t elicit the same electrical response as a leaf under attack by caterpillars.

Research Notes is written by John Wilson of the BBC World Service.
SPICEAGE-cAspiceagenetsbrochure.cmp

File Edit Network Analyse Frequency Time

Transient : t=78.2n, v=54.04

Frequency Response : Vs±615m : Vs-

COMPLEX PLANE

Group delay : t=7.76k, t=2.8u

Fourier : f=14.4M, dB=11.8

Quiescent Analysis

Node volts Node name volts

0.0000000 0.0000000
745.270745 2.58465m
62.085063 100.0000
1.1000000 19.262842

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CIRCLE NO. 711 ON REPLY CARD
CIRCUIT DESIGN

The twisted world of non-linear electronics

It is not such a big step to go from light bulbs into chaos.

Dan Ayers takes a look at both positive and negative aspects of non-linear components and circuit techniques.

Turn on an incandescent filament light bulb. Doubling the voltage across a bulb certainly does not double the current since a hot filament has a markedly higher resistance than a cold one. The common light bulb looks to the supply rather like a constant current source. This non-linear behaviour is found throughout electronics and is sometimes a curse, sometimes a boon.

A low current bulb may be used to stabilise an RC sine wave oscillator. Ideally, a Wien bridge oscillator requires an amplifier with a gain of exactly three, which in the basic circuit of Fig. 1a is determined by $1 + R_\text{f} / R_\text{p}$. In practice, small errors are unavoidable so the gain is chosen to guarantee oscillation and a non-linear element is introduced to gently keep the sine wave from drifting up to its clipping limit. A low-current bulb serves this purpose cheaply, Fig. 1b, but devices that need less current are preferable.

In effect, the bulb acts as a voltage-dependent resistor: as voltage across it increases, so does its resistance. An alternative VDR, Fig. 1c, rectifies and smooths a sample of the oscillator signal. The resulting voltage controls the drain-to-source conduction of a fet in turn controlling the amplifier’s gain.

The non-linearity of the semiconductor junction often perplexes circuit designers. Obviously there is a great difference between a diode’s forward and reverse-biased resistance but in non-linear circuit design, the relationship between the diode’s forward voltage and current is much more interesting. Incrementing forward voltage in linear steps increases current flow exponentially over a usefully wide region.

Figure 1 shows a diode network for stabilising a Wien oscillator. Unlike most stabilising methods which take several cycles to react, diode control is instantaneous, but this brings the penalty of introducing distortion. In many low-distortion designs, a positive-coefficient thermistor acts in the same way as the light bulb of Fig. 1b while, in other designs, an NTC thermistor replaces feedback path $R_\text{p}$.

Waveform synthesis

Tuned-feedback sine-wave generators like the Wien bridge oscillator may suffer from capacitor leakage and matching problems, especially at low frequencies. They can also produce an annoying bounce when their frequency is changed.

Simple square or triangle waveforms can be filtered to remove harmonics but this filtering creates a profusion of design problems. There is however another way of subtracting harmonics without filtering. It involves non-linear techniques and although it follows the same principle as digital synthesis from a sine wave lookup table, it is less complicated in practice.

The output from simple triangle wave oscillators may be passed through an exponential circuit to produce a passable sine wave. Waveform accuracy largely depends on how closely the ‘bending’ circuitry approximates the sinusoidal shape. Since the process is not a function of frequency, it doesn’t exhibit bounce or other amplitude related problems. This technique is found in several function-generator chips, including the 8938 and XR2206.

There are basically two wave shaping methods, one using inherently non-linear components, Fig. 2, and the other relying on approximating the wave by a series of straight lines, Fig. 3. Both have numerous applications.

Frequency plots for instrumentation are usually shown as decades or octaves rather than on a linear scale. In the case of a network analyser, this requires a sweep oscillator with a ten or two-fold increase in frequency for a unit increase in control voltage.

Conditioning a linear control input via a buffered diode provides a suitable non-linear characteristic through the diode’s exponential V/I relationship. A better option is to use the Vbe to Ie exponential relationship of a standard junction transistor. Temperature errors can be reduced by a long-tail pair and temperature-
Fig. 1. In basic Wien bridge oscillator, (a),
amplitude can be stabilised by replacing Ra, Rb
with non-linear networks.
Low current lamp acts as a VDR, (b), and a fet
as a voltage-controlled attenuator, (c). In (d),
diodes provide non-linear feedback.

dependent resistor, \( R_f \) of Fig. 4.
Early analogue music synthesizers relied on
combinations of voltage-controlled modules.
Since music is almost entirely based on
octaves, the modules needed exponential con-
verters to modify the linear control voltage
supplied from keyboards or sequencers.
Convenience dictated that the converters were
exponential current sources or sinks for cur-
rent-controlled oscillators or filters.
In audio, the ear’s non-linear response ren-
ders linear peak-level meters very difficult to
interpret. Levels need to be indicated on deci-
bol scales so that sound pressure change ratios
can be evaluated in terms of equivalent change
ratios in subjective loudness.

Testing for non-linearity
Linearity of DC-coupled systems is analysed
by plotting output voltage or current against
input by various means. With AC circuits, the
usual approach is to drive an amplifier with a
pure sine wave and look for distortion on the
output having notched out the drive signal
fundamental component. This leaves distor-
tion products plus noise.
A linear circuit might preserve a sine wave’s
shape, but it might also modify its phase or
amplitude (dynamic range modifiers are
described later). Close examination is possible
by analysing the original sine wave via a
notch filter. Any non-linearity adds frequency
components at multiples of the fundamental
input frequency — i.e. harmonics.
Bipolar transistor audio power amplifiers
suffer mainly from third-harmonic compo-
nents originating at crossover and odd har-
monics due to clipping. Valve amplifiers, with
their ‘soft’ overload characteristics, tend to
produce predominantly low-order odd and
even harmonics due to their different non-lin-
ear characteristics. This makes an overdriven
valve audio amplifier sound subjectively
‘warmer’ than its bipolar counterpart.
Field-effect transistors feature non-linearity
characteristics close to their valve counter-
parts. Under certain conditions they provide a
mathematical squaring function\(^2\) that causes a
notable form of harmonic distortion. Feeding
the circuit of Fig. 7 with a sine wave frequen-
cy of \( f \) results in an output frequency of \( 2f \)
since
\[
\sin^2 x = \frac{1}{2} (1 - \cos 2x)
\]
This square law can also be used to multiply
the value of two voltages together
\[
x y = \frac{(x + y)^2 - (x - y)^2}{4}
\]
Fig. 4. Exponential converters. A diode provides the function in (a) or a single transistor as in (b). Circuit (c) is the practical version featuring temperature compensation. The transistors should be thermally coupled.

Fig. 5. Logarithmic converters. A diode in feedback path (a) or transistor (b) gives inverse of exponential function. Circuit (c) is a practical version. Note similarity to Fig. 3a.

Fig. 6. Placing non-linear network in feedback of op-amp provides inverse of network function. Adjust resistors and bias for required gain and offset, take care to avoid instability.

Fig. 7. Practical circuit for using square-law response of fets. Substitution of bipolar transistors demonstrates differing curves.

Fig. 8. Basic long-tail pair configuration (a) has non-linear characteristics for large signals. Practical circuit (b) allows control over non-linear response, from linear (R minimum) to tanh (R maximum).

Basic long-tail differential pairs, Fig. 8a, behave non-linearly for large signals. For an input varying from below about -50mV to +50mV, output changes rapidly between two fixed output voltages, following a tanh transfer function.

Fig. 8b stretches the crossover region and varying the link between emitter currents via the potentiometer allows a range of functions from linear to tanh. This practical circuit was developed to simulate valve amplifier soft clipping for a guitar effects pedal. Altering the bias voltages and substituting fets may provide an even closer imitation. The CA3080 of Fig. 2 performs in the same manner.

Gain of the long-tail pair is controlled by the tail current so the circuit acts as a current-controlled amplifier. If tail current is derived from the input signal in some way, a whole range of non-linear functions become available.
Intermodulation
Feeding a non-linear circuit with a signal containing two sine waves at frequencies $f_1$ and $f_2$ results in an output including not only the two input frequencies but also a proportion of their sum and difference. This type of distortion is most undesirable for audio engineers as the extra frequencies present are not harmonically related to the input and therefore subjectively most noticeable and unpleasant.

In such circuits, the instantaneous level of one signal effectively modulates the other, hence the name intermodulation distortion. The ear's cochlea has a similar non-linear response and distorts in the same way, particularly with loud sounds. Interestingly, the ear has a curious non-linear effect known as the restored fundamental. If two signals of 800 and 1000Hz are played, the listener also hears harmonics at 800 and 1000Hz.

In audio, the benefits of intermodulation are not limited to special effects. For the radio engineer however it is indispensable. If one of the signals is a constant RF wave and the other music, the result is a modulated RF signal as used for radio communication.

Multiplier chips like the LM1496 are full of long-tail pairs and carry out modulation in a more controlled way. When used for modulating a signal, or demodulating it by the same principle, such multipliers are known as mixers to the RF engineer; when shifting the frequency of a modulated signal, they are also known as converters. Audio engineers may be more familiar with the name ring modulator.

**RMS measurement**
The RMS signal level corresponds to average power dissipated when a signal is fed a resistive load. It is obtained by applying a squaring function to the signal then taking the mean of this positive, varying level and then applying a square-root function to the DC result. By juggling a little algebra, it is possible to produce the same result with a reduction in circuit complexity and associated error, Fig. 9. Purpose-built chips provide the function but the discrete version can still offer a more economical alternative provided that you pay attention to transistor matching and thermal coupling.

If a section of the $V/I$ curve of a device 'doubles back' on itself, i.e. as voltage increases, current decreases, the device is said to exhibit negative resistance, more correctly called negative differential conductance. This characteristic allows several electronic building blocks to be constructed with a surprisingly low component count, Fig. 10.

Tunnel diodes and Gunn devices are two-terminal components exhibiting negative resistance. Suitably biased and connected they will amplify or oscillate up to microwave frequencies. For frequencies from DC to a few megahertz, negative resistance can be synthesized with conventional semiconductors.

**Companding systems**
In audio systems, it is often desirable to modify the dynamic range of the material, i.e. the difference between the softest and loudest sounds. On magnetic tape for example, the dynamic range normally available is much narrower than that of the ear.

To maintain a reasonable signal-to-noise ratio, it is possible to compress the signal on recording and expand it again on playback. Since the range of numbers between 0 and 1000 compresses to a range of 0 to 3 logarithmically, it is not surprising that audio compression and expanding — companding — involves similar non-linearity.

The common system for altering the dynamic range of a signal makes use of three basic elements — a voltage-controlled amplifier, a level tracker to extract the existing dynamic information of the signal, and circuits to change the resulting information into a control voltage used by the amplifier to impose the new characteristic onto the original signal.

Except for crude speech-quality systems, where simple fet attenuators suffice, it is rarely necessary to use discrete transistor circuitry.
CIRCUIT DESIGN

Fig. 11. Dynamic range processor basic configurations, (a) being feedforward and (b) feedback. Practical circuit (c) uses one channel of an NE570. Control allows variation in response from compression to expansion with fixed timing.

Fig. 12. Chaotic systems. Mechanical system (a) has electronic equivalent (b). In (c), quadratic portion of fet response provides non-linearity, with feedback through 'bucket bridge' resulting in chaotic response for monitoring with audio amp or oscilloscope. Circuit (d) is a self-activating version of (b) with a bipolar transistor for non-linearity and op-amp for gain. When fed to oscilloscope axes it shows a phase-space picture of chaos.

for the voltage-controlled amplifier. Integrated circuits such as the cheap, low-fidelity CA3080 operational-transconductance amplifier or the studio-quality dbx 2150A VCA have considerably simplified circuit design. VCAs are a form of multiplier working in two quadrants only.

The level-tracking element is basically a rectifier with smoothing. It can be rudimentary, in the form of a diode and capacitor, or it can feature precision rectification and variable time constant smoothing for attack and decay to allow for different programme material. Depending on the response preferred, the level can be tracked at the input of the VCA (feed-forward) or the output (feedback).

Voltage corresponding to the average signal level is then fed to the VCA via a non-linear network. The circuitry that extracts the and processes the signal level is commonly known as the side chain, as opposed to the signal path through the VCA. A device containing all the active components for a two-channel compressor or expander is the NE570, Fig. 11. On its own, it is just about suitable for hi-fi applications; an external high-quality op-amp can be added to improve noise performance.

Those who would believe that analogue electronics is dead should listen to the difference that analogue companding can make to digital audio sampling.

Chaotic dynamics

Recent developments in chaos theory have inspired a fresh look at non-linear dynamic systems. A physical example of such a system is a mass on a spring with a non-linear elasticity, Fig. 12a.

When the system is driven by sinusoidal vibrations, the mass might oscillate periodically in slightly distorted fashion at a rate related to the frequency of the driving force. If the drive frequency is changed a little however, the oscillation might stay at the same frequency, move to a different related frequency or become irregular and aperiodic.

The sequence of motion the mass moves into is known as an attractor. When the mass moves continually in an irregular manner, it has found one of the so-called strange attractors of chaos. The qualitative change from one attractor to another is known as a bifurcation and the distance between bifurcations is predictable.

Complexity of the behaviour of a chaotic seems to imply that inexplicable forces are at work but it is easy to demonstrate that a simple system can behave chaotically. Take a logistic equation sometimes used to model population growth,

\[ x_{t+1} = k x_t (1 - x_t) \]

At a given time, \( x_t \), population is a function of that of a previous instant, \( x_{t-1} \). Assuming that \( x_0 \) is initially 0.1 and \( k \) is one, \( x_t \) tends to zero. When \( k \) is two, \( x_t \) tends to 0.5 and when \( k \) is three, \( x_t \) eventually alternates between two values. When \( k \) is five, \( x_t \) tends to infinity. Within limits, when \( k \) is four the value of \( x_t \)
Chaotic circuits
In electronics, a non-linear circuit with feedback can easily produce chaotic behaviour. Figure 12c is an approximation of a logistic system. To get an idea of the nature of a chaotic system, it is possible to monitor most systems in phase space by connecting the horizontal and vertical amplifiers of an oscilloscope to different parts of the system.

Going back to the physical system of a mass on a non-uniform spring, a direct analogy is a tuned circuit with non-linear reactances. A non-linear reactance can be synthesized quite easily with standard components, but the simplest arrangement I have found for creating chaotic signals uses an op-amp to maintain the oscillation of a tuned circuit.

Because of the non-linear feedback arrangement, the oscillation produced by this circuit is chaotic as often as it is periodic. The oscillation produced by this circuit is an approximation of a logistic circuit is entirely linear. If a circuit features amplification and feedback, chaos will be lurking round the corner.

References

I found that 100 turns on a ferrite rod was adequate but it played havoc with Radio 4. Chaotic behaviour possibly lies behind many previously unexplained and partially explained phenomena – particularly where aeroplane signals such as 1/f noise are found. In the light of this theory, analysis may also offer insight into the behaviour of negative resistance oscillators – from those using Gunn diodes to unjunction relaxation circuits with their probabilistic switching points.

No component is perfect. Resistors have thermistor characteristics, diodes act as varistors... you name it. As a result, no practical circuit is entirely linear. If a circuit is chaotic, its performance will be radically different sequence of values, showing the 'butterfly effect' of sensitive dependence on initial conditions found in all chaotic systems.

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Layol is priced at £99 up to £999 (ex. carriage & VAT) which includes: Layol Schematics, 90 days FREE updates and technical support.
Layol is an entry-level PCB draughting package that will handle surface mounting and autorouting for just under £100. Dutch author Peter Baas originally designed it to take schematic data prepared on other packages, such as Orcad, so the software works well with several schematic capture tools or is happy to be used as a stand alone.

Only PCB layout was available for review — but a complementary schematic capture program should now be available — and like many cad packages, it is available in more expensive versions offering almost the same features but able to deal with circuits of differing complexity.

In practice, Layol is a collection of programs co-ordinated by a menu system called the project manager. As well as selecting the program to run, the project manager co-ordinates data files and holds configurations for different users. So several custom environments such as grid sizes, printer driver and screen colours can be saved. It is even possible to change the working language — as long as you want to work in Dutch.

The text editor, similar to Wordstar or Sidekick, is reasonable, and can be used to add menu items and batch commands to the project manager screens. Up to ten different menu screens can be created, and other packages such as a schematic capture program can be integrated into the menu structure. The editor can also be used to create and view net lists, component schedules and error files.

Selecting a PCB layout package is a daunting task: there are so many to choose from. Layol may not stick out from the crowd, but at its price, Martin Cummings finds it a reliable bet.
learned and memorised commands are no problem; but until then, the learning curve is steep, and a memory jogging card to fit over the relevant keys would have been a big help.

Moving around the screen

Three cursor styles are available, all of which include a set of unusual edge of screen cross hairs, giving the look of a flight simulator. The cursor can be moved any distance off screen and it is actually quite easy to lose. At first, retrieval seemed to be only possible by carefully studying the XY co-ordinates and working out how far and in which direction to move the mouse - frustrating as this happens surprisingly often. But a quick phone call to Pentagram revealed the well kept secret that there is a simple key press command to restore the cursor to the centre of the screen - the F key (for find?).

Snap and visible grids can be adjusted from 1mm down to 1/12800in - the finest resolution of the program - and automatic pan, if enabled, moves to the next screen as the edge of the drawing is approached. Nine zoom levels allow screen redraw around the current cursor position and also provide a method of manual panning.

One useful aid to orientation is the miniature version of the complete PCB which can be displayed in the top left hand corner of the screen. As well as the outline, all pads are shown together with current cursor position - so when zoomed in you can still keep your orientation on the overall design. The miniature also helps on those occasions when the cursor disappears off board, though as the replica is in the top left corner it is only useful if the cursor is lost below and to the right.

Of the 19 layers, eight are for tracks and the rest have predefined purposes. For example one layer is for through hole pads, two are for surface mount pads and one is for via holes. Layers can be displayed in any combination, and can be grouped for display and given a name for later reference. The layer display menu is a matrix of layers and groups; just tick the layers needed in each group and edit the name. Selection made here also determines the layers on the dot matrix printout.

Libraries

After specifying board dimensions, drill sizes and up to seven different pens - each pen defined with a width between 0.1-5mm - the first step is to create a component list. The list can either be created by picking components from the libraries and placing them on the board or by typing in an ascii file. Nine component libraries contain around 400 shapes which for layout alone, is a more than adequate supply. All the regular components are grouped for display and given a name for later reference. The layer display menu is a matrix of layers and groups; just tick the layers needed in each group and edit the name. Selection made here also determines the layers on the dot matrix printout.

System requirements

IBM compatible XT upwards
640K memory
MS-dos 3.xx or higher
Hard disk
Mouse, three button preferred
EGA graphics
Suitable output device
 Epson or HP compatible printer

Key features

Maximum board size 650mm square
16 layers
Nine component shape libraries
Design rule check
Configurable autorouter
Built-in text editor
Step and repeat facility
Macro capability

As usual, components not provided can be created using the component editor and stored in a user library. Layout seems to put an almost excessive emphasis on pad design and up to 128 pad types can be hard at any one time. The pad editor gives access to an almost infinite set of possibilities, allowing pads to be pulled and pushed from all sides to create some grotesque shapes and sizes as well as the more traditional circles, rectangles or octagons.

Components are selected from the library by name and once selected become a shape connected to the cursor ready to place. Parts rotation is conveniently achieved by clicking two mouse buttons simultaneously, and the program is reasonably successful in moving components in real time with the cursor. A useful feature is that the position of the component can be frozen while the cursor is moving. Once the cursor has been stationary for a certain time, the component moves to catch up with it. It's a technique that takes a little getting used to but it works well and, for the experienced user, speeds up placement and adjustments.

As each shape is placed the user is prompted to enter a component type, such as 74LS04, and an identifier, such as 11. The screen can display just the outline.

A miniature version of the complete PCB helps with orientation.

EPad colours indicate net status.
Start up and documentation

Installation is quick with surprisingly few questions to answer, followed by the option to change the selected video board. Several formats are supported up to 1024 x 768 pixels. Files are supplied compressed, but the two disks, when installed, fill only a relatively modest 1.5Mbytes of hard disk. A well structured directory set is automatically created, separating programs, component libraries and project files.

The spiral bound manuals immediately enhearten themselves to a user by staying open on the desk at any page. Everything is green, the logo on the packaging, the menu screens and even the disks. Presumably the green is supposed to look like the solder resist of PCBs.

In essence the user manual is a tutorial guiding the novice user through the creation of a board. While that is useful, several issues are glossed over and features are revealed in a curious order. For example, advice on basic screen manipulation such as panning and zooming is hidden in the text rather than being highlighted at the beginning.

At the end of the tutorial you are left with the feeling that there must be a lot more to the program (and it is true that a lot more exists) if only you knew how to operate it.

But all these gripes are superficial problems, only of consequence to the beginner, and a little patience, perseverance, and bed time reading of the manuals, will help the user become familiar with what is undoubtedly a competent layout package.

Layol’s autorouter performs well and is more flexible than many of its competitors.

Layol’s autorouter performs well and is more flexible than many of its competitors.

Pad design offers almost infinite possibilities.

or add either the types or identifiers for all components. A key press toggles through three options. Pin numbers can also be displayed, though they are so small that they are only visible on a high zoom factor.

Text can be added, rotated and scaled, and though only one font is supplied alternatives can be selected and others can be created with the supplied font editor. Desk top publishing in copper has yet to catch on, so the most likely application is to create and have available some special symbols – perhaps targets or alignment marks.

If Layol is used stand alone, connections are entered by pointing and clicking on the appropriate pads and a netlist is automatically compiled. The pads change colour to indicate no connection; connection but not yet routed; or routed connection, and once entered, connections can be displayed as a rat’s nest. Separate keys call up the rat’s nest for a selected pad, a selected component or the complete design.

Manual routing is trivially easy, select the width, draw the tracks and add vias when required. Horizontal and vertical movements are all logged by the program which plots the appropriate colour and layer. Any connections are allowed, but later on it is possible to run a check against the netlist. Producing buses or similarly repetitive circuitry is a piece of cake using the copy repeat function. Copy the track once, tell Layol how many more are needed and they are repeated with the same offset as used for the first copy. Such a repeat function is not unusual, but this one is refreshingly easy to use.

Complete blocks of circuitry can be picked up, moved around and copied. Again, this is useful for...
for small scale errors in the output device is not possible.

Printer output will probably limited to checking, or a prototype at best.

Final output is generated by a fairly elaborate post processor that includes drivers for HPGL, postscript and Gerber devices and Excellon drilling equipment. The post processor and photoplotter drivers can be copied and sent to a plotting bureau or board manufacturer and normal licensing arrangements are relaxed to make it easier to obtain final output even if the equipment for producing it is elsewhere or belongs to another organisation. Screens allow configuration of the layer combinations and up to 20 configurations can be defined. For example the top copper layer could require pads and vias, surface mount pads, and the upper track layer. Output can be mirrored, rotated and scaled.

One unusual facility of Lavo/'s post processor is that is provides a preview capability for a layout package. We expect most word processors to be able show graphically on screen what (hopefully) will come out on the printer. Lavo/'s post processor takes just a few seconds to generate graphics on screen, giving confidence that the correct layers have been selected and, just like the word processor, saving wasted output by illustrating user errors before they are cast in ink.

Reliable and competent

Selecting a PCB layout package these days is a daunting task, merely because there are so many to choose from and it is difficult to see what marks this one out from similar offerings.

As a stand alone draughting aid, Lavo is a reliable and competent tool and has clearly been in existence long enough to become a mature product.

Documentation is professionally presented, with plenty of screen dumps, and though not as extensive as some, it is adequate to bring an engineer or draughtsman up to speed. The libraries of shapes are adequate, and the user interface, while not the easiest to grab hold of, once learnt, is as easy as any other to work with.

Of course, cad really shows its strengths when schematic capture and layout are both automated and though the package will work happily with several schematic capture products, imminent addition of schematic capture to the product range will provide a more integrated tool set. The addition will also improve the value for money, as it looks as if the extra software will be bundled in free of charge.

So a good range of features, including multi layer and surface mount support, a respectable autorouter and adequate libraries mean that Lavo can hold its own against the competition – particularly at the lower end of the market. It will not disappoint those who invest in it.
Gravity and electric force link up in black hole?

Is it just coincidence that the ratio of gravitational to electric force of the electron is so numerically close to Planck’s time? D Di Mario presents an electron with a black hole nucleus which could shed new light on the link between gravity and electricity.

Working from three basic constants, gravitation, G, speed of light c and Planck’s constant h, we can find what is probably the ultimate quantisation of time, sometimes referred to as Planck’s time.

\[ t = \left( \frac{\pi h G}{c^5} \right)^{\frac{1}{2}} = 2.395 \times 10^{-43} \text{sec} \]

2.395 x 10^-43 differs by only 0.2% from the ratio of the gravitational to the electric force of the electron:

\[ \frac{F_g}{F_e} = \frac{Gm^2}{4\pi^2 \varepsilon_0 c^3} = 2.4 \times 10^{-43} \]

m and e are the mass and charge of the electron. Of course the other difference is that t is a time while \(F_g/F_e\) is a dimensionless number. One hypothesis which could explain such a coincidence is that the electron contains at its centre, a black hole having the Planck’s dimensions of time t, radius r = t and mass \(M = r^3G/t\).

t is so short that the very small black hole is either being created or annihilated. Its existence is time dependent but its measurable effect – a never ending variation into nothing, due to the time dilation factor – would be seen by an outside observer as the effect of a time independent entity, appearing to have all the characteristics of a charge.

A black hole would explain the dimension difference between the two equations. If the black hole were stationary (non-rotating) the two equations would have the same numerical result; rotation will cause a decrease, by a different amount, of the measurable mass and charge of the electron. Rotational speed \(U_r\) could be calculated, by relating, as an hypothesis, the fine structure constant \(\alpha\) to the rotational parameter \(U_r/c\):

\[ \frac{U_r}{c} = (1 - \alpha / 2) \]

Besides mass and charge, the vacuum permittivity \(\varepsilon\) is also influenced by the rotational
parameter to a similar extent. Other secondary quantities will feel the effect of rotation only marginally and can be safely ignored with the advantage of having only basic equations to deal with, although small numerical inaccuracies will be inevitable.

In certain instances, as a good approximation, we could take a non-rotating black hole giving, for example, \( e_0 \) with a difference of only 0.3\% from the real value. To determine \( e_0 \) we call \( R \) the \( F_g / F_e \) ratio and make it numerically equal to the equation, giving \( t \) — the case if no rotation is involved. Eventually we have \( e_0 \) in function of the three basic constants only:

\[
e_0 = R^4 / (2\pi)^2
\]

The presence of a black hole as part of an electron is also supported by the Kerr-Newman equation which must be verified when dealing with black holes. By combining the equations so far seen we may devise a relation between mass and charge of the electron which seems to obey such condition:

\[
Gm^2 = \pi e_0 e^2
\]

The approximation gives an error of 1\% and is due to the fact that, also in this case, no rotation is taken into account. A black hole nucleus allows calculation of the electron mass without using the ambiguous electron radius:

\[
m = (h^4 / \pi e^4)^{1/2} / (2 / \alpha - 1)
\]

The discrepancy is contained within 0.08\% — mostly due to the variation of volume brought about by rotation — and the equation has a part in the calculation of the proton/electron mass ratio \( m_p / m_e \). First find the term \( D \) as the ratio between the mass resulting from the above equation and the actual electron mass. Ignoring a second term which relates variation of volume with a corresponding variation in charge gives the following relation with an error of 0.04-0.09\%.

\[
m_p / m = (D - 1)^{1/2} (2 / \alpha - 1)^{1/2} (1 - \alpha / 2)^2
\]

As a consequence, the proton mass can be calculated with comparable precision. The difference between electron and proton is caused by the different rotational speed \( U_r \) of the black hole corresponding to a rotational parameter \( U_r = \alpha / 2 \). It may appear strange but calculations show that \( U_e \) and \( U_p \) produce the same charge value.

When all secondary effects are taken into account, the precision of data obtained will be in line with that already known, though the equations should be seen as support for the black hole electron rather than a way to calculate known data with more precision. Nevertheless one last equation connects the most important constants in an exact relationship: from where it is possible to calculate the gravitational constant with an accuracy at least an order of magnitude better than the current available value:

\[
G = c^5 / (2 - \alpha)\frac{(e / 4\pi)^2}{\alpha} / \pi^2
\]

\(4\pi^2\) has the dimension of a reference charge and the time dimension reflects the initial difference between the first two equations.

One way to check validity is to see if, in the coming years, the experimental values measured with higher precision tend to the value found with the above equation. This is indeed what has been happening for the past 12 years. In a letter to EW&W (Dec. 1980) the relation appeared for the first time; since then all new experimental data seem to converge consistently towards the value obtained with the last equation.

Probably there is still a long way to go before we see a comprehensive theory on electrogravity or some of its applications. On the other hand, even with the limitations of this approach, the concept of a black hole electron could be a good start.
Artificial neural networks can offer powerful processing systems.
But they must be used in the right way. Tom Ivall reports.

Are we expecting too much of the artificial neural network (ANN) in trying to make it solve whole problems rather than just bits of problems within larger, possibly hybrid, systems? According to Jim Austin, of York University, in a comment made at the IEE’s latest colloquium on the subject, Neural networks for image processing applications, this could well be the case.

He pointed out that real machine vision systems in industry were built up from multiple technologies — undoubtedly ringing a faint bell with listeners old enough to remember the hybrid (analogue-digital) computers being manufactured a few decades ago.

But in answer to Austin’s criticism, the colloquium produced one application which not only had multiple ANNs performing different functions but intended to incorporate them into a conventional digital computer system. On the same day that the Home Office announced the latest annual rise in crime figures from 11 to 15 million offences it also revealed, at the IEE meeting, how it hopes to use ANNs to save effort in crime detection through fingerprint analysis.

Automated fingerprint classification
Jacqueline Bowen, of the Home Office’s Police National Computer Organisation, is investigating multiple ANNs as alternative algorithms for automating the classification of fingerprints in national records.

In practice police try to match scene-of-crime fingerprints to the millions of fingerprint sets stored in their database. To get faster and more accurate matching, the database is partitioned into several characteristic fingerprint types, the main types identified by pattern names like arches, whorls and loops.

But the initial classification of recorded fingerprints into these broad categories normally has to be done by a human expert — a time-consuming and labour-intensive task. So there is a good case for automating the process.

Bowen is trying ANNs because they can be trained to classify patterns. Furthermore they can generalise, by making plausible classifications of patterns that were not actually presented in the training process. When trained properly, according to Bowen, ANNs can perform up to 6% better than conventional rule-based systems. The ANNs are not yet in VLSI hardware form but are currently implemented.

The whorl, an example of one of eight main pattern types used to classify recorded fingerprints held in a database. The other main types are the arch, tented arch, loop (to left and right), twinned loops (to left and right), and composite.

Irregularities in individual ridges of fingerprints; in combination these make each fingerprint unique. (As noted by anthropologist Francis Galton, cousin of Charles Darwin, in the late 19th century.)
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Great discoveries and inventions are often made at the boundary between seemingly unrelated fields. One of the most striking examples is the struggle of ideas touching on physiology and electricity in the 18th century.

The story begins in 1745 with the advent of the Leyden jar, a glass-dielectric capacitor, allowing accumulation and storage of relatively large quantities of electricity. Dutch physicist Petrus van Musschenbroek (1692-1761) found that discharging a Leyden jar through his body produced a sensation similar to a stroke given by the torpedo fish found in the Mediterranean. This led him to suggest the electrical action of the torpedo and since then the term electric fish has come into general use.1 Curiously, the German physician Engelbrecht Kämpfer (1651-1716) had likened the effect of the torpedo to lightning2 although the electrical nature of lightning was not experimentally demonstrated until 1752. Dutch scientist Willem Jacob van's Gravesande (1688-1742) had also suggested the electrical action of the torpedo, but without experimental support.

Some other fish possess the same property as the torpedo. In 1751, French naturalist Michel Adanson (1727-1806) suggested the electrical action of the southern American sheatfish. Experiments with electric fish were also performed by the French scientist Pierre Bayen (1725-1798), but they passed unobserved.3 Musschenbroek's important observation was that touching the torpedo with a sealing-wax rod produced no effect, touching the fish with a metal rod resulted in a shock - the shock felt both in water and in the air (when the fish is withdrawn from the water for a short time). But Musschenbroek gives no answer to the question he poses of whether the torpedo's electricity differs from "artificial" (frictional) electricity.4 This question was to acquire paramount importance in connection with work by Luigi Galvani (1737-1797) professor of anatomy at the University of Bologna and of obstetrics at the institute of Sciences of the Bologna Academy.

John Walsh (1725-1795) a fellow of the Royal Society of London took the next step in the torpedo fish mystery with experiments performed in La Rochelle and on the Isle of Re in the Bay of Biscay. In a 1772 letter to Benjamin Franklin (1706-1790) Walsh wrote to the inventor of the lightning conductor: "He who predicted and showed that electricity wings the formidable bolt of the atmosphere, will hear with attention, that in the deep it speeds an humbler bolt, silent and invisible: He, who by reason became an electrician, will hear with reverence of an instinctive electrician, gifted in his birth with a wonderful apparatus, and with the skill to use it."5 Walsh confirmed the observation made by Edward Bancroft (d1821) a medical officer and born naturalist, that strokes of an electric fish are felt only if it is touched at two points, one at its back and the other at its bowl. It was Walsh who identified the torpedo's double electric organs whose picture had been given in a 1678 publication by the Italian physician Stefano Lorenzini.

Fish electric organs consist of stacks of plates made up of modified muscular, nervous and ferrous cells - processes in electric fishes may be simulated by switched-capacitor circuits using mos transistors.6 The organs will be used for defence, attack, intraspecific signalling and spatial orientation, with electrical discharges produced by a series of salvos, in the Torpedo occidentalis, the impulse discharge power amounts to 6kW.

Walsh continued his research in a similar way to the earlier Leyden jar experiments, directing the torpedo's electrical discharges through four people joined in a circuit. Although the shocks in Walsh's experi-
ments were relatively weak, they were still felt by all four. Again reflecting the earlier Leyden jar tests, Walsh then discharged the torpedo through a long wire held by two persons placed on insulators, one holding the wire in one hand and touching the torpedo with a free hand from below and the other person, from above. Both experienced shocks. Replacing the wire by glass or sealing-wax resulted in null effect, results which all bore witness to the electrical action of the torpedo.

When the fish was momentarily withdrawn from water, the shocks were felt to be about four times stronger.

In experiments with the torpedo, Walsh did not obtain an electric spark, nor did he observe the attraction of a pith ball. But even at that stage of research, he was convinced of the electrical action of the fish. He wrote:

"As artificial electricity had thrown light on the natural operation of the Torpedo, this might in turn, if well considered, throw light on artificial electricity, particularly in those respects in which they now seemed to differ."

Henry Cavendish (1731-1810) was persuaded by Walsh's experiments to conduct pioneering research on electric net works, work which enabled Cavendish to disprove some objections to Walsh's conclusions. For example, answering the question of how it was possible to verify that the torpedo generates electricity if sea water is a good conductor, Cavendish explained that it was a matter of divided circuits. The resistivity of the human body is approximately equal to that of salted water so that part of the torpedo's electricity will pass through you and you will feel a shock even in water, concludes Cavendish. In discussing this issue, he uses the concept of lines of current established not until the 19th century.

"This is how Cavendish countered the observation that the torpedo does not produce sparks nor does it attract light bodies. He says we must distinguish between the quantity of electricity and the voltage (Cavendish uses the term intensity of electrification). The sensation of an electric shock, he says, depends on both the quantity of electricity passed through a body and the voltage — relatively low in the torpedo. Cavendish made a battery of 49 Leyden jars connected in parallel and charged it from an electrotastic generator to such a small degree that sparks accompanying a discharge could be seen only under a microscope. Nevertheless, the butterfly produced a shock as sensible as that given by the torpedo. Developing these ideas, Walsh found that simultaneously touching one of the poles of the torpedo's electric organ and a point between them resulted in a shock half as strong as that produced on touching both poles.

John Hunter FRS (born 1728) was also concerned with electric fishes, in particular the electric eel. In his 1775 paper, he coins the term animal electricity—a notion that was to become vital to the development of science. Walsh, the "father of animal electricity" as Hunter called him, also wanted to investigate the electric eel found in South America. But, while being Member of Parliament, he could not leave England for any length of time.

According to modern findings, the potential difference between the ends of the electric organ of the eel *Electrophorus electricus* may attain 1.2kV. The eel can produce short impulses with a power of 500V by 2A = 1000 W, enough to stun a human and allegedly kill a horse. The electric eel is usually over 1m in length (eels up to 2.5m long have been reported) and its electric organs of the fish are in its tail portion which makes up about 4/5 of the whole length. The plus and minus poles are in the rear- and fore-part, respectively, and the strongest stroke results when the head and tail of the fish simultaneously touch the most distant points of the body of a victim.

Not without difficulties, live electric eels were delivered to Walsh, and in August 1776 he produced an electric spark in the gap between foil conductors pasted onto the glass (the fish was in air, the experiment in water not succeeding).10

**Electrical evidence**

There was one more piece of evidence attesting to electrical operation of some fish.

The effect on a magnetic needle of discharge of a Leyden jar and lightning had been recognised long before the famous work of Hans Christian Oersted (1777-1851). Similarly, G W Schilling observed the effect of the electric eel on a compass needle, the effect showing itself when the needle was in water near the eel or outside the tank, as reported by him in 1769.12

These are the studies on electric fish that paved the way for Galvani's experiments in animal electricity, experiments that eventually changed our way of life.13

When in 1780 (or somewhat earlier) Galvani proceeded to his electrophysiological experiments on frogs, some scientists considered "animal electricity" to be inherent only in electric fish. Now we know that electrical processes occur in every living organism at cell level. But, macroscopically, those scientists turned out to be right.

Like other physiologists of his time, Galvani started from some "animal essences" similar to but not identical with the "electrical fluid."14 It was convenient to explain various phenomena, including psychological ones, on
the basis of mysterious essences and fluids. But the studies of Walsh, Cavendish and others showed that the electricity of the torpedo and other electric fishes did not differ from artificial electricity while featuring a relatively low voltage.

Still, such theoretical errors did not prevent Galvani from performing experiments inscribed for ever in the annals of science.

**Galvani's experiments**

Galvani's experiments were carried out using a spinal cord, crural nerves and stripped hind legs jointly articulated from a recently dead frog. By touching the spinal cord with a conductor connected to an electrostatic generator, he observed jerking of the stripped legs (the electrical excitation of nerves and muscles had been known for a long time).

After repeating and extending the experiments, Galvani and his assistants arrived at an unexpected result: the muscles contracted even though the set up was merely touched with an earthed conductor (e.g. a lancet held in the hand) while a nearby electrostatic generator (not connected) produced sparks. It was probably Galvani's wife who noticed the necessity of a spark in this experiment.15

A hundred plus years later, R Ritter used to advantage a frog's leg nerve and muscle as the "radio wave detector" in his repetition of Hertz's indoor experiments with a maximum "transmission range" of 38m (limited by the size of the basement of Berlin Physical Institute).16

The researchers supposed that the same effect ought to be obtained with atmospheric discharges. In fact, they suspended their preparation in the open air and atmospheric results obtained in muscular contractions - the preparation acting as a "lightning marker".

But the most interesting finding was still to be made by Galvani's team. Twitches were observed even in the absence of atmospheric discharges. The set up was suspended on an earthed conductor connected to an electrostatic generator, and by pressing the hook to the iron grille using a copper hook stuck into the spinal cord, Galvani invariably observed strong contractions, twitching. He obtained the same effect indoors without any atmospherics.

In his historical experiment successfully performed in October 1789, Galvani completed a muscle-iron wire-copper hook-nerve circuit. In a subsequent series of experiments, he used various combinations of metals to observe contractions of different strengths. In the autumn of 1786, the phenomenon of galvanism was discovered: the production of a current in a circuit comprised of two dissimilar metals closed through an electrolyte.

Galvani accounted for by the contact potential difference (PD) between a metal and an electrolyte and the response of the animal preparation to the electric current due to a difference in PD, between dissimilar metals.

But Galvani interpreted his discovery in another way. In his 1791 publication, he "explained" the twitching of frog legs by the discharge of a "nerveo-electrical fluid", allegedly accumulated in the muscle, which he likened to a Leyden jar.

Physicists had strong reasons to question such an explanation. Firstly, there had been the evidence linking the electricity of fishes with artificial electricity. Secondly, the analogy between the muscle and the Leyden jar was undermined by Galvani's own experiments. He noticed that violent convulsions were only observed when the "galvanic circuit" (to use a later term) contained two dissimilar metals. The Leyden jar can be discharged equally well through any conducting circuit.

**Birth of the battery**

Alessandro Volta (1745-1827) recognised the importance of galvanism. Adhering for some time to Galvani's view, at first he believed the frog's muscle to be a source of electricity. But in 1793, he definitely refuted Galvani's interpretation and rightly concluded that the frog's muscles are merely a sensitive indicator of the electric current due to the presence of dissimilar metals in contact in an electrolyte (a second kind conductor, to use Volta's term).

Even so, the Galvanists did not concede defeat, and in 1794 and 1797, they announced experiments employing only nerve-muscle preparations (without metals) and showed that twitches could be produced merely by touching nerves to muscles. More than that, Galvani the anatomist found that the electrical discharge is generated in the torpedo fish in structures similar to ordinary nerves and muscles.13

But Volta the physicist was no longer misled, and by that time was on his way to creation of the world's first DC supply, later to be known as the voltaic pile.

The whole story is a perfect example of the truth expressed by Sir Oliver Lodge (1851-1940):

"You may, by ill-luck, start with erroneous ideas, and may be aiming after something impossible to attain; but, if you keep your senses open by the way, the things you will unexpectedly hit upon turn out far more interesting and really valuable than the chimera in quest of which you started."18

The author is with the Papov Central Museum of Communications, St. Petersburg.

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**References**

10. Sigaud (ref.11), p.645.
At a discussion on the life and work of AD Blumlein held by the Institution of Electrical Engineers last October, a member of the audience asked for an update on the "official" biography which Francis Thomson has been promising for the last 20 years.

He noted that the 50th anniversary of Blumlein's death, in June 1992, passed without any sign of the biography and that as a result the public remains almost wholly ignorant of Blumlein's work. When such a request was made at the IEE's biennial conference in London, the answer was "It is the bad news. The IEE has no news. Mr Thomson is unable to produce evidence of work on such a book, that he has declined to make the material already collected available to others and that readers would be ill-advised to accede to his request for biographical material." Without further explanation,

I am happy to confirm that I have been in correspondence with Mr Thomson," wrote Edwards, "and that the Officers of the Society have agreed to accept Mr Thomson's generous offer to donate his collection of Blumlein papers to the Society. So when will this be, and when will bona fide researchers be able to read through the Blumlein archives in the Royal Society's library?

The good news is that the Blumlein archives, when available, will be subject to the Royal Society's normal rules. This is that the papers are kept secret until 40 years after the death of the subject. As Blumlein died more than 50 years ago, this means that the Blumlein papers will be available as soon as the Royal Society has them. So when will that be? Here, I fear, is the bad news.

Edwards admits that the Royal Society is "still negotiating with Mr Thomson". How will the Royal Society let people know when the papers arrive? An announcement may be made in the Society's own Journal, but no decision has been taken yet. Should I phone and enquire for the benefit of those who do not see the Society's journal, in three months perhaps? "It is likely to be taken longer than three months."

Well how long? "There is no time-scale yet.

In the absence of any more constructive suggestions from the Royal Society, I could only suggest that those who are concerned should phone the Royal Society and ask for themselves.

This suggestion did not, however, appeal to the IEE. The Institution's assistant secretary, Philips Secker, later warned the IEE meeting that to make such approaches would be "counter productive" because "negotiations are at a delicate stage".

Without further explanation, which has not been offered, it is hard to reconcile this warning with the IEE's assurance that it had received assurances from Thomson which the IEE "had no reason to doubt".

Barry Fox
Hampstead
London
Microphone challenge

We are glad that readers have risen to the challenge set by our extreme microphone preamp design published in October (Letters, EW + WW, December 1992). Herder's design is essentially the "superbal" configuration of Fletcher and Law of which readers were reminded in Circuit Ideas, (EW + WW, February 1992). Like our design the superbal CMRR is also dependent on a matched pair of resistors. Our reason for not using the superbal is that the common-mode cancelling amplifier, IC2, appears in the main signal path. The op amp's frequency response and distortion, if not its noise, will affect the output. In our design this is not the case, so a lower specification and, hence, lower power op amp can be used. In addition, to properly balance the inputs the resistors round IC2 should also be matched. The output decoupling becomes unnecessary if the output is referenced to the artificial earth applied to IC2.

The issues raised by Meunier need clarification. The recordings made with our design have been considered as of very high quality and meet the needs of the professional radio journalists and radio producer. They have been broadcast on local and national radio. This would not have happened if the microphones were being adversely affected by the circuit or made to sound muffled. We assured ourselves that the response of the M58 mentioned in the article is not affected by the load. There is almost no difference between the frequency response plots made with various loads down to a near short circuit (courtesy of Beyer Dynamic).

However, there are certain microphones, such as the AKG D202, which are essentially two microphones in one. The D202 has a bass and a treble element with a crossover to combine the outputs. The load presented by our design does affect the sound of a D202 giving a bass lift which many find more pleasant. This effect is not perceptible with microphones with a more conventional construction, such as the Beyer M58 or hypercardioid Beyer M201. The self-induced current damping effect in a microphone is insignificant since, unlike a loudspeaker, the transduction efficiency is very, very low, both from acoustic to electrical energy and vice versa. Perturbing microphone responses is not really an issue in practical recording since there are no dynamic microphones nor rooms in which recordings are made that have a flat response. The real issue is whether the recordings sound crisp and clear, and they do.

Meunier's suggestion of introducing a parallel load resistor will always make the signal to noise ratio worse. The attenuation of the signal will be more than the reduction in thermal noise. Assuming a noiseless amplifier the SNR will degrade by

$$\frac{R_s + R_L}{R_L}$$

if a load resistor is placed in parallel with the source. For an arbitrarily complex network between the signal source and the amplifier, adding a dissipative component can only worsen SNR, never improve it. If only this were true!

Adrian Pickering and Max Hadley
University of Southampton

Power for the people

I am an undergraduate at City University and working in a group advising a company, Intermediate Technology (a charity involved in helping under-developed countries help themselves), on a project to improve power distribution to remote villages in Nepal. Power distribution relies on the villagers acquiring vehicle batteries and shuttling them between recharging points and their houses.

Due to the distances involved and the weight of the batteries the villagers tend to leave it to the last minute before recharging. This is leading to seriously reduced battery lives and the villagers having to somehow get more batteries which they cannot easily afford.

We are working on methods of reducing the distances the villages have to haul the batteries, efficient recharging methods, and discharge limiting the batteries. This involves looking into power distribution networks, inverters, basic recharging circuits, and very basic discharge limiters to be attached to the batteries.

I would be grateful for any viable solutions which have to be cheap and use components, skills and equipment that are available in Nepal.

Peter Vivell
Ashford
Middlesex

Making links

Antiquaries will know that Andrew Ainger in his letter "Keeping an ear to the ground" (EW + WW, December 1992) describes a system conceived by Steinheil, Bavaria, in 1838. Among pioneers of Steinheil's system was Trowbridge, USA, who, around 1875, proposed the system for transatlantic signalling. In the U.K. Preece developed a practical system before the turn of the century with a range of about 6km.

However, Steinheil's system was allowed to die following demonstrations of Marconi's system, but was resuscitated during WW1 with the name earth currents but, before 1900, was originally attributed simply to electromagnetic induction. My father operated earth current signalling equipment during WW1 and from information he gave me, I made a device based on a buzzer and valve amplifier in 1935 which let me communicate with a school friend who lived a mile or so away.

More than half a century later, after a career as an agriculturist, my interest was rekindled and during experiments with a tuned system, I was able to maintain reliable communication at 10km, though this was by no means the limit. Carrier frequency was less than 10kHz so as to comply with DTTI regulations.

George Pickworth
Kettering
Northants

Working assumptions

Recent suggestions of ways to revive the economy have included large scale building projects and lower taxes on cars. Meanwhile the media and communications industries remain silent. It is not as if there haven't been job losses and cut backs in these sectors - all major computer, electronics, and communications companies have made staff redundant. What we are seeing is the unopposed erosion of our invisible infrastructure.

Construction, transport, power supply, and heavy manufacturing industries have all lobbied for support for their sectors of the economy, sectors that we have always thought of as the invisible infrastructure. Managers recognise the effects on their businesses of housing shortages for staff, train delays, power cuts, and traffic jams, and call for improvements to made to the infrastructure.

Yet the fact that their marketing departments could not get their message to the customer due to the ineffectiveness of the media has never been an issue. This flaw in the invisible part of the infrastructure has brought our consumer driven economy to a halt. Products have been designed for mass appeal at the expense of usefulness to overcome the deficiencies of the mass media.

There is no lobby for the invisible
Safe radiation

Anthony Hopwood's article "Natural radiation focused by power lines: New evidence" (EW + WW, November 1992) contrasts sharply with the recent publication by the Health and Safety Executive: "The tolerability of risk from nuclear power stations" (HMSO - 1992) which states: "Ionising radiation and radioactive materials can readily be detected and measured, even in small quantities, by sensitive instruments. The annual dose to people in this country from radioactivity in the ground, radioactivity in our bodies from birth or acquired since, and cosmic rays is about 1mSv, with about a third coming from each of these sources. This value is an average. The dose to individuals may differ from the average by a factor of between 2 and 3, either higher or lower."

The effect postulated by Hopwood is thus within the range of natural variation and does not provide any reason to depart from Sir Richard Doll's conclusion in his report "Electromagnetic fields and the risk of cancer" (National Radiological Protection Board - 1992) that: "The epidemiological findings that have been reviewed provide no firm evidence of a carcinogenic hazard... that might be associated with residence near major sources of electricity supply".

DE Jeffers
The National Grid Company
Guildford Surrey

Quantum folly

The focusing of natural radiation by power lines (EW + WW, November 1992) appears to be entirely consistent with the view that processes of computation have their origins in electromagnetic phenomena most accurately explained in terms of the quantum theory of physics. The directional differentiation effect near power lines suggests the influence of phase quadrature and therefore that accurate analytical models for computational purposes could be constructed using the methods of projective geometry and electronic holography applied to artificial neural networks.

The direct links between quantum physics and computation now being firmly established suggest that this is what might otherwise be called a "quantum" medicine. That so many of the teaching hospitals in London should be closed or amalgamated on supposedly commercial grounds seems to be yet another folly of the present government. Their combined expertise will soon be needed.

Brian Richmond
Crickhowell Powys

Peer pressure?

The findings and theory in Anthony Hopwood's article "Natural radiation focused by power lines: New evidence" (EW + WW, November 1992) were presented at the public inquiry into NGC's proposal to put up new overhead lines from Teesside to York. We felt that we could not press the arguments very far in view of the absence of direct evidence to support our position. It would be best to wait for the results which are now appearing from all parts of the world. You will be probably be shown that the two mechanisms are complementary and hence synergistic.

As I see it, this explanation has a very similar status to the free radical cage escape mechanism which occurs in the presence of EMF and which gives rise to the same kind of chemistry in biological cells as high energy radiation. I have to say, however, that there is in my view more convincing experimental correlation in the latter case. In the end it will probably be shown that the two mechanisms are complementary and hence synergistic.

I must congratulate your journal on having been in the forefront in publicising the effects of EMF. I am sure I don't need to tell you that there is enormous vested interest on the part of industry to suppress the results which are now appearing from all parts of the world. You will be happy to hear that NGC's lawyers attempted to dismiss reports in EW + WW as being of low scientific status on the grounds that the articles were not "peer reviewed". I was able to point out that neither are articles in some journals consisting of papers from EW + WW to read before they come to their conclusions at the termination of the inquiry.

Professor G. Scott
Newby Cleveland
not parallel and bearings are measured relative to them. These problems would have occurred no matter how accurately the null was sensed, but that could not be very accurate. The major problem getting an accurate MF-bearing, particularly at night, was that an ordinary loop is just as sensitive to horizontally polarised skywave as it is to vertically polarised ground wave. Errors in skywave causes are large but often steady over several minutes. Averaging by dips or other methods will not smooth them out.

If Lipschutz proposed Adcock type aerials to get over this he must have been unaware of the mechanics of these aerials on an aircraft. A deflection away from the vertical of only a few degrees is quite enough to re-introduce enough horizontal polarisation to bring back skywave problems, and if they were made short and stiff enough not to deflect in the airstream he would have been forced to tell the pilots never to bank, climb or dive?

There are many other points that could be made, but it all goes to prove that ideas are cheap, it is the hard slog of actually making them work that matters. Perhaps those civil servants and assessors of 1939 were not quite as stupid as Darrington makes them out to be!

WF Blanchard
Dorking
Surrey

Course notes

As a retired RAF Engineering Officer I followed with interest your article “Pursuing a lost course” (EW + WW, May, 1992) and the ensuing correspondence.

Sir Edward Fennessey totally ignored the fact (Letters, July) that the air war was not fought over the Northern part of Germany or Europe, but also in the Middle East - Cyrenaica, Crete, Malta, and North Africa, as well as Italy and Yugoslavia, where effective radio aids were mostly unreliable. This applied to both the bomber and fighter force. Had Heinz Lipschutz’s invention not been rejected, it is possible that it would have been available to the RAF and allied air forces which would then have been totally independent of all ground aids - even the W/T.

It is difficult to understand why the invention was rejected without some evaluation, considering its importance if proven a valid idea to put it mildly.

When my squadron, No 274 (Hercules) desert air force, was tasked to support our ground troops in the battle for Crete it meant a sortie of at least 500 miles from our base at Gerawla, a few miles East of Mersa Matruh, to Crete and return. The squadron faced air battles over the island and was obviously unable to land and refuel. Navigational aids were primitive and our pilots found great difficulty in finding Crete and returning to base.

Lipschutz’s inertial navigational system would have been a godsend. Had this invention been fully proved for operational use, then not only would INS have been available to the allied air forces in Europe and the Middle East, but eventually it could have been supplied by Britain to the US air force in its battle against Japan.

Proven in war it would have been a money spinner for this country, for not only could we have sold it to the air forces of the world but also to civil aviation, thereby guaranteeing many, many jobs for a skilled engineering force.

Barry Wilkinson
South Wales

Human problems

True as some of your November editorial may be, it is surely the primary purpose of formal education to prepare each generation of students for the problems - including the human problems - they will meet in their working lives, in Europe.

In the next half century or so the vast economic effects of global population growth will certainly be faced by the developed nations.

Unwelcome as it may be to those currently studying advanced MMIC technology, a fundamental knowledge of human nature is also necessary. This can most easily be acquired by some awareness of the humanities and at least a modicum of managerial ability.

It is the lack of the latter which seems to have been an endemic British disease after WW2 I doubt if academics who have never faced the problem of finding the next pay packet for their employees are the best surgeons to remove this canker.

A considerable part of the British defence - and electronics - industry was built up on the iniquitous cons-plus system which completely inhibited the creation of competent responsible management. It wasn’t necessary since the government - and thus the taxpayers - already paid for all the mistakes and errors of judgement.

We thus have nearly two generations who were kept cooly employed by this system which was abandoned very early across the Atlantic. One only has to gaze at the moronic yuppies travelling round the M25 at above the legal speed, and at the same time using their cellular phones, to question their managerial ability - or if their journeys are necessary at all. Certainly a misapplication of electronics.

Your remarks about German widgets are perhaps more aptly applied to those emanating from the Far East. Having worked in various countries in which German competition was evident, I have experienced high technical ability matched with managerial efficiency. Perhaps this is the result of a highly disciplined population and rigid economic control. Germany’s economic power certainly does not derive from the production of widgets.

In conclusion let us encourage entrepreneurs in the 21st century, whether they have studied the sciences, arts, or neither.

Tourism may still be a valuable national economic asset in the future to attract the millions in the Pacific Rim. Are there not opportunities in many disciplines, all of which have some electronic content, in mass transportation, medical science, environmental protection, waste disposal, mass catering, food distribution, affordable family holiday accommodation, and so on?

If Lipschutz’s work about German electronics was mostly unreliable. This is not only because of the quality of the science and engineering, but also because of the generally low status of science and engineering, and the lack of the kind of focus that the German system achieved.

It is necessary to look far beyond Maastricht. Brussels will never produce entrepreneurs. It will strangle them before birth.

M Le M Mansoon
Squadron Leader RAF (retired)
Acdita
Italy

Importance of history

I think you are wrong about an history course (EW + WW, November 1992). All citizens should have some general knowledge of history, not just the history of battles and politics but also of technology, art, design, and music. This knowledge can only diffuse down from the people who are experts in each area. If you remove the experts and semi-experts, the average person will become increasingly ignorant.

The chief reason these courses run, however, is that there is a demand for them from potential students. The subjects are naturally interesting and rewarding to study. The problem with courses on worthy subjects such as electronics or chemical engineering is that they are not popular - most people see technology as difficult, boring, or downright wicked. If there was a big demand for engineering courses, the money would naturally follow.

So long as they are scraping the bottom of the barrel to try to keep up their student numbers, the course standards, the financing, and the motivation of the lecturers will all be poor.

The problem lies further back, perhaps in the schools, perhaps in TV programming, perhaps in the relevance of magazines with “Power lines cause cancer” all over the top?

Don Cox
Middlesborough
Cleveland

No future

Your observations regarding the standing of science and engineering in this country are depressingly true (Comment, EW + WW, October 1992). The decline in the UK economy is a direct result of this standing.

You only have to look at the jobs pages in the electronics press to see how low the status of science and engineering has dropped. At £20,000 for senior engineer level posts with countless years of experience and a list of required qualifications a mile long, why bother? Plumbers can diddle more than that on cash jobs.

My son is six years old and I can see an engineer in him now. But not if I get my way. It’s going to be the medical or law profession for him. Engineering is an enjoyment for me, but struggling to pay the mortgage and running old cars is part and parcel of it. Not for him won’t be!

Derek E Coleman
Wales

...Temps perdu

The French long wave station France Inter is somewhat unusual as it also transmits talking and music as well as the second pulses. I have no information on this station, but I know the frequency is 163.8kHz, I will soon be 70 years old and would love to build a clock using this French transmission. Do any of your readers know of any addresses to which I could write for information circuits or anything at all to do with time code transmissions in general. I wrote to the French Embassy some time ago but have had no reply.

RMW Quail
Caythorpe
Lincolnshire

LETTERS
The long-tailed pair has proved a seminal influence in analogue circuit design, ever since it first appeared. Ian Hickman explores the LTP's flexibility.

Before semiconductors, a double triode was about as close as anyone could get to a monolithic matched pair. In a sensitive, high input impedance valve voltmeter, designed accurately to measure DC levels, drift was a major problem. The HT circuit could be stabilised easily enough, but heater supplies were more expensive to tackle. A double triode allowed any change in anode current for a given grid voltage in one half of the valve, due to heater voltage/cathode temperature change, to be cancelled for the main part by a similar change in the other half.

One of the earliest applications of the long-tailed pair LTP was at DC, in valve voltmeters, Fig. 1a. But when transistors came on the scene, the LTP really came into its own. Early versions employed selected discrete transistors, packaged in a common heatsink to avoid temperature differences. Later, single can devices like the 2N2060 came on the scene, offering even lower drift in DC coupled circuits.

The LTP is useful in a host of AC applications as well, Fig. 1b showing just one. It also has many uses at RF. Figure 1c shows how the basic LTP can be used as an RF modulator. When LTPs are piled up together, things really start to get interesting.

The LTP is useful in a host of AC applications as well, Fig. 1b showing just one. It also has many uses at RF. Figure 2a shows a seven transistor "tree", which forms the basis of many modulator/demodulator/mixer circuits. The baseband-to-RF conversion conductance is set by the value of $R$, the total resistance between the emitters of the lower LTP. Each of the two outputs is double balanced in its own right, containing neither carrier nor baseband components – at least, if the circuit is ideally symmetrical.

The circuit produces a double sideband suppressed carrier output and, used in conjunction with a suitable sideband filter, forms a simple SSB exciter. While it could be built using discretes, an IC implementation provides close matching of all the components, and the provision of separate constant current transistor tails for the lower LTP enables the conversion conductance to be set with a single resistor, Fig. 2b. The larger this resistor, the lower the conversion conductance, but the more linear the circuit operation becomes.

By contrast, the upper LTPs are operated without any such emitter degeneration. Their job is to switch the current smartly at their emitters to one or other collector cir-
Fig. 2a) The basic seven transistor tree double balanced modulator.
b) An IC version is available from many manufacturers under type numbers such as LM1496, LM1596. Note: pin numbers refer to the round G package.
c) Simple test circuit using 1496. Note: pin numbers refer to the DIL P package.

circuit with as little delay as possible. To this end, the amplitude of the carrier is made large compared with the 100mV or so needed to switch the upper LTPs; alternatively, a square wave carrier can be employed.

An MC1496 was connected into the circuit of Fig. 2c, ready for some practical measurements, but first we should look at some of the illustrations in the data sheet. Figure 3a shows the DSB output of an MC1496, the (suppressed) carrier frequency being 500kHz and the modulating frequency 1kHz. Spectrum, Fig. 3b, shows the carrier to be almost completely suppressed, the device providing a typical suppression of 65dB at 0.5MHz and 50dB at 10MHz carrier frequency respectively. Carrier suppression is optimised by applying a null adjustment to the bases of the lower LTP, to cancel out any standing Vbe offset. If such an offset is deliberately introduced, then a standing carrier component will be present in the output. This permits the production of (full carrier) AM (amplitude modulation), Fig. 3c, which shows very nearly 100% modulation. The spectrum is shown in Fig. 3d.

Amplitude modulation is used for broadcasting on the long, medium and short wavebands and is simply recovered from the incoming signal with a diode detector. The detector charges up a capacitor to the peak of the RF waveform, whilst a resistor in parallel with the capacitor enables the voltage to leak away again.

The RC time constant used is long compared to the period of the RF, but short compared to that of the highest baseband frequency, enabling the detector output to follow the peaks of the RF
down into the troughs of the modulation. Due to the large disparity between the baseband and RF frequencies, the individual cycles of the latter are not visible in Fig. 3c, but in fact the carrier is continuous, and the waveform exhibits no phase changes.

This is illustrated in Fig. 4a, where, for clarity, a much lower RF has been used; the modulation depth is 96% and the baseband waveform is shown as well for comparison. The RF waveform here looks sinusoidal rather than square because I have cheated slightly. The waveform shown was actually produced by an MC1495 which is a four quadrant multiplier, rather than by an MC1496 with its cell of four switching transistors. An active double balanced modulator like the MC1496 would of course usually be used with a tuned tank circuit rather than with resistive loads as in Fig. 2c, providing a sinusoidal output.

In contrast, if the AM modulation index is allowed to exceed 100%, then there are sudden 180° phase changes apparent in the RF waveform - see Fig. 4b which was produced using the circuit of Fig. 2c. A diode detector is only sensitive to the amplitude of the peaks, not to their phase, and so the recovered baseband audio would be a grossly distorted version of a sinewave.

An interesting case arises when the modulating frequency is the same as the RF carrier frequency, \( f_c \). The double balanced modulator or mixer then acts as a phase sensitive detector, producing the sum and difference of the modulating and carrier frequencies. As these are in this case identical, the results are \( 2f_c \) and \( 0 \)Hz, i.e. the second harmonic and a dc term. The value of the latter term can be anything from a peak positive value, through zero, to the same peak value but negative, depending upon the relative phasing of the inputs at the carrier and modulation ports of the mixer.

Figure 5a shows a circuit where the two inputs are in phase, which results in a peak positive output at one output port of the mixer and peak negative at the other. If, moreover, a large signal is used so as to overdrive the modulation port, the second harmonic output becomes small, one output remaining “stuck high” and the other “stuck low”.

The exceptions to this are the two instants each cycle where the input waveform passes through zero, at which points all transistors must be conducting equally. This results in narrow spikes, Fig. 5b, which are rich in harmonics (the slightly rounded shape of alternate half cycles is due to the single ended drive to the modulation port). This circuit can thus be used as a frequency multiplier: for example, using a 5MHz input from a standard frequency source; the outputs could be combined in a tuned push-pull tank circuit so as to extract any desired harmonic of 10MHz.

With further overdriving of the modulation port, or by using a clipped sinewave drive, the spikes become very narrow, enabling very high order harmonic generation to be achieved simply.

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Acknowledgments
Figures 2b, 3 and 4a are reproduced by courtesy of Motorola.

Fig. 5a) Circuit used for harmonic generation. b) Waveforms at the outputs of circuit shown in a).
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February 1993 ELECTRONICS WORLD+WIRELESS WORLD
Even the simplest active devices may exhibit baffling behavioural problems. No diode is perfect, and their imperfections are fascinating – even two-terminal devices are quite complex.

Serialised from the book Troubleshooting Analog Circuits by Robert Pease.

All diodes start conducting current exponentially at low levels, nA and up, and an ideal diode may have an exponential characteristic, with a slope $\Delta V/\Delta I$ of:

$$g = (38.6mS/mA) \times I_F$$

where mS = milliSiemens = millimhos, and $I_F$ = forward current.

Indeed transistors do have this slope of 38.6mS/mA at their emitters, at room temperature, corresponding to 60mV/decade of current. But the slopes of the exponential curves of different real (two-terminal) diodes vary considerably. Some, like a 1N645, have a slope as good as 70 or 75mV per decade. Others like 1N914s have a slope as poor as 113mV/decade; or have intermediate values such as 90mV/decade.

But the data sheets never tell you about this. To tell the truth, I didn’t even recognize the fact myself when I wrote the first version of this, as published in EDN. I assumed the slopes started out from 60mV/decade and then worsened – shifted over to 120mV/decade at higher current levels. But I was wrong – and nobody ever contradicted me.

Figure 1 shows just a few of the different curves you may get when you buy a diode. None of these slopes is characterised or guaranteed. Changing supplier will also have an effect, so each supplier should carefully checked for a particular application.

As the current level continues to increase, the conductance per milliampere deteriorates due to series resistance and high-level injection and other non-linear factors. So, at a large forward current, a diode’s forward voltage $V_F$ will be considerably larger than predicted by simple theory, and larger than desired. Of course, some rectifiers, depending on their ratings, can handle large currents, from amperes to kiloamperes. But the $V_F$ of all diodes, no matter what their ratings, err from the theoretical at high current levels.

Schottky diodes can now have smaller $V_F$ than ordinary PN diodes. But even germanium diodes and rectifiers still have their following because their low $V_F$ is similar to the Schottky’s: some new germanium Schottky diodes are supposed to have even lower $V_F$.

High-speed and ultra-high-speed (sometimes also called high-efficiency) silicon rectifiers are also available, designed
ANALOGUE DESIGN

Fig. 2. In this diode-evaluation circuit (a), transistor Q1 simply resets $V_x$ to ground periodically. When the transistor turns off, $V_x$ rises to about 0.6V at which point the diode starts conducting.

In (b), when $dV_x/dt$ is 8V/µs, this 1N4148 overshoots as much as 140mV at input frequencies below 10kHz before it turns on. At higher frequencies - 120, 240, 480, 960, and 1920kHz - as repetition rate increases, overshoot shrinks and disappears. Maximum overshoot occurs when $f_x < 7$kHz.

In (c), when $dV_x/dt$ increases to 20V/µs, this same 1N4148 overshoots as much as 450mV at 7kHz but only 90mV at 480kHz and negligible amounts at frequencies above 2MHz.

In (d), various diode types have different turn-on characteristics. The superimposed, 120kHz waveforms are all invariant with frequency except for the bad 1N4148.

for fast switching-regulators and other high frequency applications. They don’t have quite as low $V_F$ as Schottky diodes and are not quite as fast. But high reverse-voltage ratings are available and so they are useful for certain switch-mode circuit topologies that impress large flyback voltages on diodes.

Reverse-bias problems

But it is reverse-biasing various diodes that leads to really wild dissimilarities.

For example, the guaranteed reverse-current specification, $I_{r(e)}$, for many types of diodes is 25nA max at 25°C. Yet measuring them reveals that many have merely 50 or 100pA of leakage.

The popular 1N914 and its close cousin, the 1N4148, actually do have about 10-15nA of leakage at room temperature because of their gold doping. So although these diodes are inexpensive and popular, it is wrong to use them in low-leakage circuits since they are much leakier than other diodes with the same leakage specs.

So why do some low-leakage diodes have the same mediocre 25nA leakage spec as the 1N914?

Diode manufacturers set the test and price at the level most people want to pay because automatic test equipment can test at the 25nA level — but no lower! — without slowing down: characterising and testing a diode for 100pA or better means paying extra for the slow-speed testing. Of course, high-conductance diodes such as Schottkys, germaniums, and large rectifiers have much larger reverse leakage currents than signal diodes, but that is not normally a problem.

For a very-low leakage diode, use a transistor’s collector-base junction instead of a discrete diode. The popular 2N930 or 2N3707 have low leakage, typically. Some 2N3904s, do, too, but some of these are gold-doped and are leakier.

The plastic-packaged parts are at least as good as the TO-18 hermetic ones. Of course, high-conductance diodes such as Schottkys, germaniums, and large rectifiers have much larger reverse leakage currents than signal diodes, but that is not normally a problem.

Speed Demons

When a diode is carrying current, how long does it take to turn the current off? Slow diodes can take hundreds of microseconds. For example, the collector-base junction of a 2N930 can take 30ps to recover from 10mA to less than 1mA, and even longer to the nA level. This is largely due to the recombinations time of the carriers stored in the collector region of the transistor.

Other diodes, especially gold-doped ones, turn off much faster — down into the nanosecond region. Schottky diodes are even faster, a lot faster than 1ns. But this may still be in parallel with a PN junction turning off slowly at a light current level. If a Schottky turns off from 4mA in less than 1ns, there may still be a few µA that do not turn off for a µs: so if using a Schottky as a precision clamp that will turn off very quickly, as in a settling detector, don’t be surprised if there is a long tail.

Switching regulators need diodes, high-current rectifiers and transistors to turn off quickly. If the rep rate is high, the current large and the diode turns off slowly, it can fail due to overheating.

Do not try a 1N4002 at 20 or 40kHz as it will work very badly, if at all. Sometimes, if only a moderate amount of current is needed at high speed, several 1N914s can be used in
Fig. 3. Even though the diodes in the first stage of the op amp are forward or reverse biased by only a millivolt, the impedance of these diodes is much lower than the output impedance of the first stage or the input impedance of the second stage at high temperatures. Thus, the op-amp’s gain drops disastrously.

**Strange diode effects**

Leds kept in the dark make an impressive, low-leakage diode because of the high band-gap voltage of their materials. They can exhibit less than 0.1pA of leakage when forward biased by 100mV or reverse biased by 1V. Of course, a diode does not have to be reverse-biased to give a leakage problem.

In one hybrid op-amp I was designing, I specified that the diodes be connected in the normal parallel-opposing connection across the input of the second stage to avoid severe overdrive (Fig. 3). But in operation the op-amp’s voltage gain fell badly at 125°C because the diodes were IN914s, and their leakage currents were increasing from 10nA at room temperature to about 80mA at the high temperature. Remember that the conductance of a diode at zero voltage is approximately (20 to 30nS/mA) x Ileak.

That means each of the two diodes really measured only 6kΩ, and because the impedance at each input was only 6kΩ, the op-amp’s gain fell by a factor of four, even though the diodes may have only been forward or reverse biased by a millivolt.

Substituting transistor collector-base junctions for the diodes put the gain back up where it belonged: you cannot safely assume the impedance of a diode at zero bias is high if the junction’s saturation current is large. For example, at 25°C a typical IN914 will leak 200 to 400pA even with only 1nV across it, so an IN914 can prove unsuitable as a clamp or protection diode - even at room temperature – despite having virtually no voltage biased across it, in even simple applications such as a clamp across the inputs of a fet-input op amp.

**Zener, zener, zener...**

Just about all diodes will break down if too much reverse voltage is applied, but zener diodes are designed to break down in a predictable and well-behaved way. The most common problem with a zener is to starve it: pass too little current and it may get too diode-connected transistors make nice, fast, low-leakage diodes. Their capacitance is somewhat more than the 1pF of the IN914.

Parallel – an emergency solution that can work well. But long-term reliability is suspect. The best approach is to engineer the right amount of speed for a circuit. High-speed, fast recovery, and ultra fast diodes are available.

The Schottky rectifiers are even faster, but not available at high voltage breakdowns. Anyone designing switching regulators at these speeds should really know what they are doing – or at least wear safety-goggles.

**Turn off – turn on**

Logic diodes like the 1N914 are popular because they turn off quickly – in just a few nanoseconds – much faster than low-leakage diodes. What is not well known is that these faster diodes not only turn off fast, they usually turn on fast too.

For example, feeding a current of mA towards the anode of a 1N914 in parallel with a 40pF capacitance plus a scope probe or something similar, usually causes the 1N914 to turn on in less than 1ns. Thus, the Vf has only a few millivolts of overshoot.

But with some diodes, even 1N914s or 1N4148s from some manufacturers, the forward voltage may continue to ramp up past the expected DC level for 10 to 20ns before the diode turns on. The overshoot of 50 to 200mV is quite surprising (Fig. 2).

Even more astonishing, the Vf overshoot may worsen at low repetition rates, but can disappear at high repetition rates (Fig. 2b-d).

I spent several hours once discovering this particular peculiarity when a frequency-to-voltage converter suddenly developed a puzzling non-linearity. The thickest part of the problem with the circuit’s diodes was that diodes from an earlier batch had not exhibited any slow-turn-on behaviour. Further, some in a batch of 100 from one manufacturer were as bad as the diodes in Figs. 2b and 2c. Other parts in that batch and other manufacturers’ parts had substantially no overshoot.

When confronted, the manufacturers at first tried to deny any differences. But eventually they admitted that they had changed some diffusions to “improve” the product. One engineer’s “improvement” is another’s ruination so always be alert for production changes that may cause problems. Changing the diffusions, process or masks may have a major effect on a circuit.

Many circuits require a diode that can turn on and catch, or clamp, a voltage moving much faster than 20V/µs. For consistency in a circuit with fast pulse detectors (for example), qualify and approve only manufacturers whose diodes turn on consistently. As with any other unspecified characteristic, be sure to protect against “bad” parts by first evaluating and testing, then specifying the performance required.

Also, to see fast turn-on of a diode circuit with low overshoot, keep the inductance of the layout small. It only takes a few inches of wire for the circuit’s inductance to make even a good fast rectifier look bad, with bad overshoot.

One “diode” that does turn on and off quickly is a diode-connected transistor. A typical 2N3055 emitter diode can turn on and off in 100ps with negligible overshoot and less than 1pA of leakage at 1V, or less than 10pA at 4V. (This diode does, of course, have the base tied to the collector.) But it can only withstand 5 or 6V of reverse voltage, and most emitter-base junctions start to break down at 6 or 8V. Still, these
noisy. Many have a clean and crisp knee at a small reverse-bias current, but this sharp knee is not guaranteed below the rated knee current.

Some zeners will not perform well no matter how carefully they are applied. In contrast to high-voltage zeners, low-voltage (3.3 to 4.7V) devices are poor performers and have poor noise and impedance specs and bad temperature coefficients — even if they are fed a lot of current to get above the knee, which is very soft.

The reason is that, at voltages above 6V, zeners are really avalanche-mode devices and employ a mechanism quite different from (and superior to) the low-voltage ones, the real zener diodes. At low-voltage levels, band-gap references such as the LM336 and LM385 are popular, because their performance is good compared with low-voltage zeners.

Zener references with low temperature coefficients, such as the 1N525s, are only guaranteed to have low temperature coefficients when operated at their rated current — about 7.5mA. Adjusting the bias current up or down, can sometimes tweak the temperature coefficient, but some devices are not happy if operated away from their specified bias.

Also, do not try to test an IN825 to see what its "forward-conduction voltage" is because in the "forward" direction, the device's temperature-compensating diode may break down at 70 or 80V, damaging the device's temperature-compensating diode.

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If a really high-current zener is needed, a power transistor can help (Fig. 4).

Zapping

A diode tends to fail by becoming a short circuit when overpowered — and zeners cannot absorb as much power as might be expected from short pulses. But can IC designers take advantage of this situation? The answer is yes!

Zapping is a useful technique for testing zeners. If a really high-current zener is needed, a power transistor can help (Fig. 4).

The LM329 is popular as a 6.9V reference and stability, such as 5 or lOppm per 1000h, typically.

In its LMI08, National Semiconductor (Tempe, AZ) wrote about zener zapping first and used it extensively. Monolithics (Santa Clara, CA) wrote about zener zapping first and used it extensively. Monolithics (Santa Clara, CA) wrote about zener zapping first and used it extensively.

The buried zeners in the LM129/ LM199/LM169 series also have better stability than most discrete references (1N525 or similar) when the references are turned on and off — and before you subject a zener to a surge of current, check its derating curves for current vs time, which are similar to the rectifiers' curves. These curves will show why you cannot put an amper into a 10V, 1W zener for very long.

In fact, most rectifiers are rated to be operated strictly within their voltage ratings: exceed that reverse voltage rating, break them down, and their reliability will be degraded. To evade unreliability, redesign the circuit to avoid over-voltage, or add in an R-C-diode damper to soak up the energy; or find a controlled-avalanche rectifier.

The rectifiers are rated to survive (safely and reliably) repetitive excursions into breakdown when their rated breakdown voltages are exceeded. Manufacturers of the devices can also give you a good indication of how to keep out of trouble.

If only a zener will do to conduct a surge of current, take a look at the specially designed surge-rated zener devices — also called transient-voltage suppressors — from General Semiconductor Industries Inc (Tempe, AZ). Their 1W devices, such as the 1N5629 through 1N5665A, can handle a surge of current better than most 10W or 50W zeners.

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Zapping

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The V(f) of an op amp usually depends on the ratio of its first-stage load resistors. IC designers can connect several zeners across various small fractions of the load resistor. When they measure the V(f), they can decide which zener to short out — or zap — with a 5ns, 1.3-18A pulse. The zener quickly turns into a low-impedance (=1Ω) short, so that part of the resistive network shorts out, and the V(f) is improved.

In its LMI08, National Semiconductor (Tempe, AZ) wrote about zener zapping first and used it extensively later on. Although the technique is useful, make sure nobody discharges a large electrostatic charge into any of the pins that are connected to the zener zaps. Zeners really do make a cute lightning flash in the dark when they are zapped, but be careful not to hit them too hard if you don’t want them to zap and short out.

Zener zaps are also becoming popular in digital ICs under the names of "vertical fuses" or, more correctly, "anti-fuses". If an IC designer uses platinum silicide instead of aluminum metallisation for internal connections, the diode resists zapping.

Opto-isolators

An opto-isolator, also called a photo-coupler or opto-coupler, usually consists of an infrared led and a sensitive phototransistor to detect the led's radiation. Working with the cheaper 4N28 means it may be necessary to add circuitry to achieve moderate speeds. For example, tailoring the biasers per Fig. 5, will push the response of a 4N28 up toward 50kHz; otherwise the devices can not even make 4kHz reliably. The trick is decreasing the phototransistor's turn-off time by using a resistor from pin 4 to pin 6.

I've evaluated many different makes and lots of 4N28s and have found widely-divergent responses. For example, the overall current gain at 8mA can vary from 1.5 to 104%, even though the spec is simply 10% min.

Further, the transfer efficiency from the led to the photodiode varies over a range wider than ±1%, and the β of the transistor varies from 300 to 3000. As a result, the transistor's speed of response, which is of course related to β and 1/β, would vary over a ±10% range. If a circuit does not allow for gain and frequency response varying so wildly, expect trouble.

For example, two circuits, one an opto-isolated switching regulator and the other a detector for 4-20mA currents, have enough degeneration so that any 4N28 will work. Data sheets for optoelectronic components often don't have a clear V(f) curve or list any realistic typical values, often listing only the worst-case values. So it may not be realised that the V(f) of a led in an opto-isolator is a couple hundred millivolts smaller than that of discrete red or infrared leds.

Conversely, the V(f) of high-intensity, or high-efficiency, red leds tends to be 150mV larger than that of ordinary red leds.

Solar cells

Extraneous, unwanted light impinging on the PN junction of a semiconductor is only
How can diodes fail?

If a diode is expected to turn on and off, but instead does something unexpected, that unexpected behaviour may not be a failure, but it could certainly cause trouble.

You can kill a diode by applying excessive reverse voltage without limiting the current or by feeding it excessive forward current. When a diode fails, it tends to short out, becoming a small blob of mushy silicon rather than an open circuit. I did once see a batch of 1N4148s that acted like thermostats and went open-circuit at 7°C, but such cases are rare these days. One of the best ways to kill a diode is to ask it to change up too big a capacitor during circuit turn-on. Most rectifiers have maximum ratings for how much current they can pass, on a repetitive and on a non-repetitive basis. I have always been favourably impressed by the big Motorola (Phoenix, AZ) books with all the curves of safe areas for forward current as a function of pulse time and repetition rate. The curves take a little understanding, but after a while they are fairly handy tools.

Manufacturers can play other tricks than just changing processes. Fortunately reverse-marked diodes are pretty rare these days. But I once built a precision test box that worked right away and gave exactly the right readings — until I picked it up to look at some waveforms. Then the leakage test shifted way off zero.

After some study, I narrowed the problem down to an FD100 diode, whose body is a clear glass DO-35 package covered with black paint. This particular diode’s paint had been scratched a little, so when I picked up the test box, the light shone under the fixture and onto the diode.

To minimise such problems I recommend the following strategies:

- Have each manufacturer’s components specifically qualified for critical applications.
- This is usually a full-time job for a components engineer, with help and advice from the design engineer and consultation with manufacturing engineers;
- Establish a good relationship with each manufacturer;
- Require that manufacturers notify when, or preferably before, they make changes in their products;
- Keep an alternative source qualified and running in production whenever possible.

one of many tricky problems encountered when designing and operating precision amplifiers — especially high impedance amplifiers. Just like a diode’s PN junction, a transistor’s collector-base junction makes a good photodiode, but a transistor’s plastic or epoxy or metal package normally does a very good job of blocking out the light.

When light falls onto the PN junction of any diode, the light’s energy is converted to electricity and the diode forward biases itself. If a load is connected across the diode’s terminals, useful amounts of voltage and current can be drawn from it. A number of large-area diodes could be stacked in series and used for recharging a battery — the most unreliable part of this system is the battery. Even if they are not abused, batteries do not like to be discharged a large number of cycles, and will eventually refuse to take a charge.

But the most critical problem with solar cells is their packaging. Most semiconductors do not have to sit out in the sun and the rain as solar cells do, and it is hard to make a reliable package when low cost is — as it is for solar cells — a major requirement.

In addition to packaging, another major trouble area with solar cells is their temperature coefficients. Just like every other diode, the $V_T$ of a solar cell tends to decrease at $2mV/°C$ of temperature rise. Therefore, as more sunlight shines on the solar cell, it puts out more current, but its voltage could eventually drop below the battery’s voltage, whereupon charging stops.

Using a reflector to get even more light onto the cell contributes to this temperature-coefficient problem. Cooling helps, but the attendant complications rapidly overpower the original advantage of solar cells’ simplicity.

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3. A 0.02Hz to 2MHz full featured sweep/function generator producing sine, square, triangle, skewed sine, pulse and a TTL output and linear or logarithmic sweep. Outputs of 50Ω and 600Ω impedance are standard features;
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For most small users, Seetrax Ranger1 provides a sophisticated system at an affordable price. It is better than EasyPC or Tsi/en's Boardmaker since it provides a lot more automation and takes the design all the way from schematic to PCB - other packages separate designs for both, that is, no schematic capture. It is more expensive but the ability to draw in the circuit diagram and quickly turn it into a board design easily makes up for this.

Source JUNE 1991 Practical Electronics

Many Radio Amateurs and SWL’s are puzzled. Just what are all those strange signals you can hear but not identify on the Short Wave Bands? A few of them such as CW, RTTY, Packet and Amtor you’ll know – but what about the many other signals?

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CIRCLE NO. 129 ON REPLY CARD

CIRCLE NO. 130 ON REPLY CARD

February 1993 ELECTRONICS WORLD+WIRELESS WORLD 139
LOW POWER RADIO LINKS

There is considerable interest in low power radio telemetry and related applications following recent UK deregulation. The DTI no longer requires licensing for certain types of low power radio link provided that the equipment meets an approved specification and is used in accordance with the regulations. Wireless data links have never been easier says Ian Hickman.

Here is a typical application; design a personal alarm for the elderly or infirm enabling the wearer to summon help at need, from anywhere in the house or garden.

Until recently, such a device could not be built without submitting the whole unit for type approval under the relevant MPT specification. New regulations now permit this type of system to be built and sold without type approval provided that the RF part uses type approved radio modules.

Available from a number of manufacturers, many modules are designed with a specific end use - such as security systems - in mind. The modules which constitute the subject of this article are totally uncommitted. This means that the purposes to which they can be put are limited only by the user’s ingenuity, the mode of operation being determined by the nature of the peripheral circuitry with which he surrounds them. The modules in question operate in the band 417.90 - 418.10MHz and are type approved to MPT1340: general telemetry, telecommand and alarms, which specifies a maximum ERP of -6dBm, i.e. 250µW. Please bear in mind however that they must be used in accordance within the terms of their type approval (see box Transmitting the letter of the law).

Module characteristics

The TXM-UHF transmitter module is a sur-

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**Fig. 1** a) Block diagram of the TX-UHF transmitter module. b) Connections in recommended test circuit. c) The output of the transmitter module following 20dB of attenuation, 10mV/division vertical, 1ms/div horizontal, 12V supply, no modulation. d) As c except 9V supply, 100µs/div horizontal, 2-kHz squarewave modulation applied.
face acoustic wave oscillator, varactor modulator and RF output filter. I constructed a test jig for the module by mounting the hybrid device on an odd piece of strip-board as a means of connecting power, modulation, etc. Of course, anyone who contemplates constructing a UHF circuit on strip-board needs his head examining, but in this case all the hot circuitry is on the module, with only dc and low frequency inputs supplied via the strip-board. The RF output was connected to a couple of inches of 50Ω coax, the other end of which was terminated in a BNC plug.

The rated output of the unit at 12V is -3dBm ERP, which would correspond to 159mV rms into a 50Ω load. The trace in Fig. 1 looks like a very nice sinewave; it must be said that at 418MHz, the scope would show even a squarewave as pretty well sinusoidal. This is incorporated in order to limit the transmitter’s OBW (occupied bandwidth) due to the higher Q of the varactor at the high frequency inputs supplied via the strip-board.

The annexe 2 items, not exempt from licensing, are shown in Table 2. Some of the frequency allocations are the same as, or adjacent to annexe 1 allocations, the difference being that in general the licensed devices are permitted a higher ERP.

Fig. 2 a) The SILRX-418-A Receiver block diagram. b) Basic receiver test circuit (see text). c) The transmitter circuit used with b. d) The receiver audio (upper trace) and data (lower trace) outputs before and after transmitter switch-on.
by suppressing the higher order FM sidebands.

With a TX dc supply of 9V and the modulation input strapped to 0V, the frequency was 417.96MHz and, strapped to +9V, 418.01MHz. This is well within the maker’s initial frequency accuracy specification.

The close-in spectrum of the transmitter when transmitting 30Hz squarewave modulation at ±25kHz deviation indicates an OBW of less than 128kHz at the -50dB level. The far out spectrum shows all harmonics to be more than 50dB down, thanks to the transmitter’s output bandpass filter.

The SILRX-418-A receiver is a double superhet design, the block diagram being as in Fig. 2. The receiver was mounted upon another scrap of strip-board ready for testing in conjunction with the transmitter. The circuit was as shown, except that a BC234 was used instead of the BC558 and its 47kΩ collector load was replaced by an 820Ω resistor in series with an LED. The transmitter was switched on half way through the trace, the audio and data outputs up to that point being just noise and clipped noise respectively. Following switch-on, the audio output is a 20Hz squarewave exhibiting considerable sag, due to partial differentiation by the inadequate modulation coupling time constant. There is also an initial transient dc level shift, as the 10μF blocking capacitor charges up. The data output is a cleanly sliced version of the audio, with the initial transient also suppressed.

In applications such as telecommand, while the transmitter only needs to be powered to send a command, the receiver must usually be ready to receive at any time (the rare exceptions being systems where commands need only be sent at pre-determined times). If the receiver is battery operated, a pulsed squelch system with a duty cycle of about 1% on-time in the absence of signals saves power. If the presence of a signal is detected (a matter of two or three milliseconds from switch-on), the DETECT signal may be used to extend the on-time to receive a command.

Figure 3, taken with a data modulation of 200Hz, shows the switch-on of the transmitter’s +9V supply, exhibiting over two milliseconds of switch bounce, while the lower trace shows the receiver’s recovered data output. The first negative-going edge about two milliseconds after the end of the TX switch bounce looks a bit suspect, but thereafter things are fine so clearly the data settling time is well within the maker’s figure of 10ms although that is quoted with a 5V receiver dc pullup.

Table 1. Exempt devices.

<table>
<thead>
<tr>
<th>Use</th>
<th>Frequency</th>
<th>Maximum ERP</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Induction communications systems</td>
<td>0-155 kHz and 240-175 kHz</td>
<td>See specification transmitter output is ±200kHz maximum</td>
<td>MPT 1237</td>
</tr>
<tr>
<td>Metal detector</td>
<td>0.148-6.5 MHz</td>
<td>See SPEC 1984/1940</td>
<td>N/A</td>
</tr>
<tr>
<td>Access and anti-theft devices and passive transponder systems</td>
<td>2.32 MHz</td>
<td>See specification</td>
<td>MPT 1239</td>
</tr>
<tr>
<td>Telemetry, telecommand and alarms</td>
<td>25.27 MHz</td>
<td>1 mW</td>
<td>MPT 1346</td>
</tr>
<tr>
<td>General telemetry and telecommand</td>
<td>46.72 MHz</td>
<td>1 mW</td>
<td>MPT 1328</td>
</tr>
<tr>
<td>Short range alarms for the elderly (VHF)</td>
<td>52.73 MHz</td>
<td>0.5 mW</td>
<td>MPT 1338</td>
</tr>
<tr>
<td>General telemetry and telecommand (UHF)</td>
<td>173.35 MHz</td>
<td>1 mW</td>
<td>MPT 1339</td>
</tr>
<tr>
<td>General telemetry and telecommand (VHF)</td>
<td>173.53 MHz</td>
<td>1 mW</td>
<td>MPT 1330</td>
</tr>
<tr>
<td>Fixed alarms</td>
<td>273.25 MHz</td>
<td>1 mW</td>
<td>MPT 1344</td>
</tr>
<tr>
<td>Fixed alarms</td>
<td>273.50 MHz</td>
<td>250 mW</td>
<td>MPT 1340</td>
</tr>
<tr>
<td>Transmitter and mobile alarms</td>
<td>473.90 to 475.00 MHz</td>
<td>500 mW</td>
<td>MPT 1329</td>
</tr>
<tr>
<td>Mobile telecommand and telecommand</td>
<td>475.00 MHz</td>
<td>100 mW</td>
<td>MPT 1374</td>
</tr>
<tr>
<td>Surface models</td>
<td>49.95 MHz</td>
<td>50 mW</td>
<td>MPT 1385</td>
</tr>
<tr>
<td>General purpose low power devices</td>
<td>49.95 MHz</td>
<td>10 mW</td>
<td>MPT 1326</td>
</tr>
<tr>
<td>Radio microphones and radio hearing aids</td>
<td>173.25 MHz</td>
<td>250 mW</td>
<td>MPT 1345</td>
</tr>
<tr>
<td>Low power microwave devices</td>
<td>2450-2455 MHz</td>
<td>10 mW</td>
<td>MPT 1345</td>
</tr>
</tbody>
</table>

Fig. 3 Receiver data settling time test, upper trace (5V/div) RX data output (TX modulated at 200Hz), 2mV/div horizontal.

(a) TIME BASE = 500μs/DIV.
CH1 V/DIV = 0.2V.
CH2 V/DIV = 5V.

(b) TIME BASE = 200μs/DIV.
CH1 V/DIV = 100mV.
CH2 V/DIV = 2V.

Fig. 4 a) The TXM-UHF and SILRX-418-A can handle linear signals, with some distortion; 1kHz full amplitude sinewave modulation applied to TX module (lower trace) and as recovered by the receiver (upper trace).

b) At a reduced modulation level (upper trace) the distortion of the received signal is negligible, although the effect of a reduced level into the data slicer is evident (lower trace).
supply against the 9V used here).

To test system linearity using the signal from the receiver's AF output terminal, the TX was modulated with an 7.5V pk-pk sinewave, Fig. 4a, lower trace, and the RX audio captured - upper trace - for comparison. The result looks just a little bit secondish, the positive peaks too rounded and the negative too peaky, but clearly the link would be capable of transmitting analogue data.

Figure 4b shows the recovered audio (upper trace) when the modulating sinewave was reduced to 3V pk-pk and clearly the distortion is very low indeed - at the sacrifice of some 8dB path loss capability. On the other hand, with the reduced deviation and consequently reduced input to the data recovery circuit, the slicer is finding it rather hard work (data output, lower trace).

However, with a reduction in path loss capability of just 6dB relative to binary modulation, it would be perfectly possible to operate the link with four levels rather than just the two of plus or minus 25kHz deviation, preferably with some linearisation in the modulator to give equally spaced levels at the receiver.
Two bits per symbol could therefore be transmitted, doubling the maximum bit rate throughout.

With the proliferation of unlicensed transmission systems it might seem that mutual interference would make them unusable. The more so since many of the bands are too narrow to allow channeling. A number of factors prevent this from being a real problem in practice, at least for the present.

Firstly, the ERP is purposely limited to a fairly low level. Thus while the modules featured here might give a range of several kilometres under exceptional circumstances — with elevated antennas on a large flat plain without trees or other obstructions — the manufacturer quotes reliable maximum range over open ground (with antennas mounted at a height of only 1.5m) of 200m, while excessively obstructed paths (with buildings etc) and/or antennas less efficient than 1/4 wave whips may in extreme cases reduce the reliable operating range down to some 30m.

Secondly, the devices are designed (for the most part) for intermittent operation, e.g. in telecommand applications. Even a telemetry application will not normally broadcast continuously, but send batches of readings at pre-defined intervals or on telecommand.

Thirdly, even though a receiver may pick up a transmission not intended for it, these devices are commonly operated with an address code as a header to each transmission, and a receiver can thus ignore a transmission not labelled with its own particular address code.

The first two points reduce the possibility of a wanted transmission being jammed by an unwanted, and the third minimizes the possibility of inappropriate response to the reception of an unwanted signal.

**Coding**

While NRZ (non-return to zero) data, typified by the reversals illustrated in Figs 2 and 3, could be used, a popular and commonly employed mode of signalling used with low power radio modules uses both 0 and 1 logic levels for each data bit, making the code (like Manchester code) self clocking. A typical example is the Motorola range of cmos devices MC14026 (encoder) and MC14027/028 (decoders). These 16 pin devices have nine pins dedicated to setting addresses and/or data bits. Each pin can be connected to ground (low), to Vdd (high) or can be left open circuit. Thus data is binary, permitting in principle the transmission of \(3^2 = 19683\) different codes. The MC14027 interprets the first five trinary bits as address giving \(3^5 = 243\) different addresses, the remaining four bits being interpreted as data. For the four data pins, an open is interpreted as a logic 1, so only \(2^4 = 16\) different data messages are available. The MC14028 interprets all nine pins as addresses, but with the same limitation on address pin 9 as the data pins on the MC14027: consequently 2 X \(3^8 = 13122\) different addresses are available, but only a single data bit (received or not received), indicated by the VT (valid transmission) flag. With either receiver, two consecutive valid addresses followed by identical data must be received before the new data is latched and the VT flag set.

Dl switches with a choice of three ways per pole are rather rare and so another popular scheme, typified by the 18 pin DIL plastic devices by Holtek, type number HT12E (12-bit encoder and HT12D (8-bit address and 4-bit data decoder) uses address/data pins with binary selection.

### Table 2. Non-exempt devices.

<table>
<thead>
<tr>
<th>Use</th>
<th>Frequency</th>
<th>Maximum ERP</th>
<th>Specification</th>
<th>Application form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio frequency induction loop data systems (higher power non carrier systems)</td>
<td>0-18 kHz</td>
<td>See specification - frame rate output is above 10 watts</td>
<td>MPT 1370</td>
<td>RA77</td>
</tr>
<tr>
<td>Wire data (received or not received), indifferent addresses are available, but only a single data bit (received or not received), indicated by the VT (valid transmission) flag. With either receiver, two consecutive valid addresses followed by identical data must be received before the new data is latched and the VT flag set. Dl switches with a choice of three ways per pole are rather rare and so another popular scheme, typified by the 18 pin DIL plastic devices by Holtek, type number HT12E (12-bit encoder and HT12D (8-bit address and 4-bit data decoder) uses address/data pins with binary selection.</td>
<td>0-18 kHz</td>
<td>See specification</td>
<td>MPT 1370</td>
<td>RA77</td>
</tr>
</tbody>
</table>

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3: The GPS message on the hardware platform

The data content of the GPS message is both complex and subtle...
Complex because it carries corrections ranging from relative movement to relativity, yet subtle because it was originally designed to be decoded without help from powerful microcomputers.

Philip Mattos examines the connection between system software and hardware.

The GPS message conveys the information needed by the receiver to operate the system. It is made up of two distinct parts: that which relates to the satellite transmitting the data, and that which relates to the overall system.

The former is known as the ephemeris, although it includes more than just orbit parameters, and the latter is known as the almanac.

The message frame from the satellite consists of five subframes, each of length 300 bits. This corresponds to a data rate of 50 baud for six seconds. The first three subframes contain the ephemeris information, satellite clock information, and the status of the satellite. These repeat every frame, i.e., every 30s. Subframes 4 and 5 contain the system pages, and continue to cycle for 12.5 minutes before repeating, with each one having a page identity to indicate its contents.

Inside the subframe, the data is coded very tightly in binary, because in the early seventies when the system was designed, memory was very expensive.

Each subframe consists of ten 30-bit words, with a preamble in the front of the first, and a 6-bit checksum or parity field at the end leaving 24 useful bits of data. Some fields have to be assembled from different areas of the message, and all are fixed point binary, with the scale factors given in the specification. The early design era of the format shows here too remembering that the 8-bit micro was not born until about 1974, the 16-bit until 1978. Some values are scaled in semicircles, to avoid multiplication operations in the receiver, and the orbit radius is given as a square root because the processor in the receiver of that era would have had difficulty with this calculation. All the GPS calculations have to be done in at least 48-bit floating point, usually 64-bits.

All the data from the satellite is transmitted in the form of coefficients for the orbit or clock description equations given in the specification. The user must plug in the exact time into these equations to calculate the position of the satellite.

The almanac contains the orbit data and clock data and satellite health, to less accuracy than the ephemeris but with a semi-infinite validity. The curve fit used to generate the data relates to the whole orbit, and the trends of the orbit, rather than just a four hour segment.

The almanac is used by the receiver to...
choose which satellites are currently available in the sky. These are then acquired, and the more accurate ephemerides downloaded for positioning.

In addition, the almanac contains information to model the ionosphere, and to calculate the difference between GPS time and UTC... and even a 22-byte message in ASCII.

Once the ephemeris message from the satellite has been loaded, the continuing information needed from it is timing. By monitoring the propagation delay of each satellite against its internal clock, the receiver can track very accurately the relative delays of the four satellites in use. These are known as the pseudo ranges, once converted to metres using the speed of light. The term "pseudo" is used because they are not true ranges, firstly because they are relative, secondly because they need correcting for the errors in the satellite clocks, and thirdly because they need correction from the speed of light, due to ionospheric, tropospheric and relativistic effects.

These corrections are covered later.

The accuracy of tracking the satellites can be illustrated by looking at the speed of light... 300,000,000 metres per second. Thus one microsecond, the length of a code chip on the commercial signal, is worth 300 metres in range measurement, and due to geometrical magnification, up to a mile in horizontal position. Thus the signal must be tracked to an accuracy of 10 nanoseconds, to give 3 metres in range and 20 metres in position, if the receiver is not to become a dominant error source for the system.

Satellite position calculations

Before the user position can be calculated from the pseudo ranges, the satellites' positions at that instant must be calculated. This is a two-stage process, because the position when the signal was transmitted is needed, not its position on reception, and the correction between the two cannot be made unless both user position and satellite position is known. Thus a first approximation is made using the current estimate of user position, yielding an approximate expected propagation delay. This value is subtracted from the time of reception, and a new position for the satellite is found. In this way, 350m is about 0.2 metres... of relevance only to shallow angles, so the pseudo range error around 0.2... millimetre accuracy is achieved in one step.

The reason for the plethora of data is that the orbit is complex. It takes account of the accuracy required, the various gravitational densities of parts of the earth, the earth's magnetic field, the effect of the moon (both directly and via sea and land tides on earth) and even solar wind on the space craft. All these perturb the orbit. These perturbations are monitored by tracking stations on ground, using GPS in reverse (multiple receivers, one transmitter) to produce an accurate curve fit predicting the orbit for the next few hours.

User position calculation

Once the satellite positions are known, a start can be made on calculating the user position. There are four unknowns: the position in the X,Y,Z axes, and the offset of the user clock, T. There are also four equations, each being a simple Pythagorean calculation of range between the user and the satellites.

\[ R_i = \sqrt{(X - X_i)^2 + (Y - Y_i)^2 + (Z - Z_i)^2} \]

for \( i = 1 \) to 4 where \( X_i, Y_i, Z_i \) is the position of the \( i \)th satellite.

This would be the intersection of three spheres, and only three satellites would be needed, so note that we do not know the actual range \( R_i \), but the difference in range between one satellite and all the others. This is, mathematically, the intersection of three hyperboloids, and, while it is soluble, it is very messy.

The usual method is to let the user position be \((X, dX)\) etc; and multiply it out. Then ignoring second order terms (e.g (9dX,dY)), the equation linearises to:

\[ [A][dX \, dy \, dz \, d\theta] = 0 \]

where \([A]\) is the cosine matrix of angles from the user to each satellite, \( c \) is the speed of light, and \( t \) is the user clock error.

This is solved to produce a correction to each axis, and is then repeated from that new position until the corrections are so small that the calculation is deemed complete.

The algorithm converges very rapidly. One example with an initial error of a million metres converges to 17km in one step, to 3.5m in the next, and better a micron in the third... clearly dwarfed by other errors.

Corrections

There are four corrections made to the measured pseudoranges. They are covered below in order of magnitude.

Satellite clock

The satellites carry Caesium standards as main clock, dropping back to a Rubidium standard, and then finally an ovened crystal. Despite running from an atomic standard, drift must occur. This is constrained to be less than a millisecond, the epoch of the


**Ionospheric**. The ionosphere distorts the measurements by delaying the passage of the signal. The delay is variable, depending on the electron density in the ionosphere, and the angle that the signal passes through it. The characteristics of the ionosphere change with time of day, due to exposure to the solar wind, but also with the seasons, and the 11 year sunspot cycle.

Because the delay is proportional to the square of the frequency, it is possible to eliminate it by making measurements on two frequencies. For this reason, GPS satellites also transmit on 1226MHz, known as L2, but the commercial signal is not available on this frequency. The commercial user must make corrections using a mathematical model.

A default set of parameters are supplied in the specification, but these are updated by those sent with the almanac pages. There are eight parameters that describe two features, the vertical delay, and its variation with time.

The ionospheric error leads to about 80m of position error, reduced to about 30m by the use of this model, which is known as the Klobuchar model after its inventor.

**Electronics World + Wireless World February 1993**

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**Possible candidates Sats 0-1**

**Possible candidates Sats 0-2**

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**Selective availability**

Selective availability is the deliberate distortion of the system by the US Department of Defense. They feel this is necessary to prevent the enemy using the full accuracy of the system for weapons directed against the USA.

Originally it was expected that the civil system with one microsecond code bits would be far less accurate than the military one at 100m, and the military system could always be denied to the enemy.

However over the twenty year development of the system, receivers became so sophisticated that they could track the carrier wave (see below) at 600ps per cycle, leapfrogging this barrier.

Selective availability works by dithering the clocks of the satellites in a random manner. It is adjusted to give horizontal errors of up to 100m 95 percent of the time, 300m the remaining 5 percent, with vertical error about 50 per cent worse. It can also be operated by transmitting distorted orbit information.

The military receivers can remove these distortions by decrypting coded parameters in the navigation message. The decryption keys are dynamic, and change frequently, and must be distributed to any user who needs this accuracy, for instance in time of war.
Differential GPS

Almost all the errors of the GPS system can be removed by using two sets of equipment, one at a fixed location, the other at points to be surveyed. The first set can then correct for all the errors seen, even errors in the maps in use, and by transmitting these corrections to the second set, enable it operate “perfectly”.

The errors that remain are the tracking noise in the two receivers, clearly not common to the two sites, and the secondary effect of any other error that results from the distance between them.

The two sets must use the same group of satellites. Given that, the simplest solution is to transmit a lat-long-height set of corrections and this is fine for a small separation. Its advantage is that it only needs a single monitor site.

Next level is to transmit pseudo range corrections. This is valid up to about a thousand kilometres, and still uses a single monitor. The final and most advanced level is to separate the corrections into orbit corrections and satellite clock corrections (and ionosphere corrections).

This last, known as Wide Area Differential GPS (WADGPS), is at an experimental stage, and depends on a fixed network of monitor stations that can effectively triangulate the satellites. The corrections are then broadcast on a geostationary satellite such as the Inmarsat series.

These types of differential GPS all yield positions accurate to around 5m, in real time, even in motion.

To go further, either long term integration, or carrier phase methods are needed.

Carrier phase positioning

The ultimate accuracy from GPS is achieved by using the output of the carrier phase tracker in differential mode. As with conventional differential GPS, the orbit and ionospheric errors, and selective availability are all cancelled by using the two receivers. The wavelength of the carrier wave is about 20cm, so a phase locked loop which can track it to 5º is achieving a spatial resolution of about a centimetre.

The problem is (see Figs. 3 and 4) that we do not know which particular cycle of the carrier we are tracking, as the code tracker is usually only accurate to a few metres. This is known as cycle ambiguity. It is resolved by considering all the possibilities, which may be 10m of range, ie 50 cycles, on each of four satellites, ie three differences, making 125,000 possibilities, and finding which are most precise solutions. As the satellites move, the residual errors on each change on all but one, the correct one, so that after about ten minutes, one can be certain of the correct choice.

Until very recently this work could not be done in real time, so the tracking data from both monitor and local receivers was logged, and the true position/separation calculated by post processing.

Recently, with the very accurate narrow separation correlator code tracker from Novatel in Canada, researchers at the University of Calgary have been able to reduce the ambiguity considerably, so that the work can be done in real time. This receiver is so precise that its code tracker is accurate to six centimetres rms without using carrier phase correction, which ought to give direct solution to the ambiguity equations. However, nature is not kind... the ionosphere delays the code, but advances the carrier by the same amount, so code solutions do not translate directly to carrier solutions.

Another manufacturer, Ashtech (San Jose, Calif), claims one centimetre plus one millimetre per kilometre of separation between the two receivers.

System hardware

This article is based on the design and construction of a complete automotive GPS system, from antenna to map display. The board shown in the photograph takes the signal from the radio, samples it, feeds the samples to the computer. This processor performs all the GPS tasks to generate the position, and also the map handling tasks such as reading the map data from the flash eprom card and controlling the framestore that generates the RGB video signals. The final stage combines the four (including sync) video wires onto a single PAL or NTSC composite video coax for the TV monitor.

The 7.7 x 3.5in board is a passive backplane supporting modules 3.5 x 1.1in wide. Each module has a standard 16-bit bus organisation, with the 3.5 dimension being chosen to allow use on a PC/XT add-in card.

Seven module widths are used here, being a single width module for the sampler, the 16-bit correlation processor, and for the RGB to composite encoder, with two double width modules for the flash eprom card and the main CPU with video store.

Signal Path. The circuitry of the sampler module is shown in Fig. 5. The input from the radio is DC-blocked by a large value capacitor to allow the use of radios with a DC offset. The coax, which may have considerable length if the radio is remotely sited, is then terminated in a suitable resistor to prevent reflections. One stage of a 74HC04 inverter is used to amplify the signal after the cable loss. This is done by using a high value resistor from output to input to bias the inverter to its linear transfer region. It then exhibits very high gain, and generates cmos logic levels at the output if overdriven. A second inverter stage without the feedback sharpens up the edges. This produces a logic level signal corresponding to positive and negative half cycles of the radio noise output. The information content is contained in the timing of the transitions.

The signal is then fed to the input of a 74HC164 shift register, clocked at 2.046 MHz, twice the GPS code chipping rate. When the shift register is full, its contents are latched into the 8011 link adapter, which transmits it up a two wire serial link to the transputer memory.

Clock generation. A 10.23MHz oscillator is constructed using two unbuffered 74HC04 inverter stages. Note the difference from the conventional single inverter TTL oscillator using a series resonant crystal: this design allows the use of a parallel resonant crystal. This arrangement can accept microprocessor controlled varactor diode tuning in a version for professional use. A third inverter is used to buffer the oscillator output, so that varying loads do not affect the frequency.
The oscillator drives a 74HC390 dual decade counter.

The first counter is configured as divide by 2 and divide by 5 counters in parallel, generating 2.046 MHz for the sampler clock, and 5.115 MHz as a frequency reference to the computer. The second decade counter is configured to divide by 8, and is fed from the 2.046 MHz signal. This generates 256 kHz to send packed bytes of samples to the transputer.

Control. The above completes the circuitry for embedded systems as in a car. To allow the sampler to be used in a system where the transputer boots its code from, and sends its screen information to, a PC, the sampler must be stopped while booting up. This is achieved with a flip-flop that is cleared by the reset signal, and clocked by the first byte of data sent to the link adapter. The QV, or data available signal is used, as the data bits themselves could power up in either state. The flip-flop output holds the sampler clock counter in the reset state until a byte is sent by the program.

The eight output data-bits are available for any control uses in the system. In the map dis-

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The Transputer

The Inmos transputer was launched in 1985, some seven years after the company was founded with British government funding. The concept was to provide a computing component that could be interconnected with additional transputers to give the required processing power. The concept has similarities with adding transistors in an amplifier to give the required level of gain. The enabling transputer feature is the serial link, which allows direct connection between processors, or from processor to peripheral, without any hardware glue logic, and without any software to slow down the communications or hog the CPU.

Less visible, but just as essential is the hardware scheduler that allows several jobs to share the CPU without any software overhead. Jobs usually relinquish the CPU voluntarily, by performing some i/o transfer that must await an acknowledgement. If they do not, however, they will be put to the back of the queue after about one millisecond. This sounds short, but is on average about 10,000 instructions.

The transputer architecture was designed to allow compilers to operate efficiently. It is called a risc machine by many, but also has many high level instructions, and while most RISC machines have many registers, the transputer has only three. These are stack organised, to minimise opcode length by removing addressing. The small number was chosen after much simulation on real programs as the best compromise between the inefficiencies of creating temporary registers in memory, and the inefficiencies of storing away unnecessary registers on context switches.

The correlation transputer is the 16-bit T225. It has a CPU with a 50ns (20MHz) instruction cycle, four serial links, 4K bytes of 50ns static ram, and system services all on chip. There is an external memory interface that can mix 8 and 16-bit memory on the same bus, and of course the hardware scheduler that allows parallel programming and operation of independent or interacting jobs.

The main compute engine is the 32-bit T805. Note the structural similarity between the two, the only differences are the data-bus width, the addition of a 64/80 bit floating point unit (FPU) and a much more flexible external memory interface. In fact, with the exception of the instructions that execute in the FPU, and some image handling instructions, the same instructions execute on both machines. The image handling instructions were omitted from the 16-bit machine as it is unlikely that a video frame store would be attached to a 16-bit machine.

The memory interface on the T805 is programmable to set the cycle timing and strobe phasing to suit almost any type of memory, and it also generates the control signals and refresh addresses for dynamic ram. This allows the connection of low cost dram, as well as video ram in the car map-display application.

In the GPS environment, we use the links to connect the radio. This allows the transputer, but a second link was used to drive the keyboard and screen, allowing the provision of up to three control consoles, for example chart table, steering position and flying bridge.

In the car version, two transputers are used, so the link between them is just the two wires, and ROM is only provided on one. The other is booted over the link.

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The T225 transputer is CPU, memory, comm and services on the same chip, running at up to 30 MHz.
play version, they are used to strobe the user input buttons around the screen. In the panic button version, they are used to drive the 16 character text display.

**The 16-bit correlation processor.** The 16-bit processor has two tasks... to boot the system, and to perform the dull repetitive task of correlation that reduces the bandwidth of the GPS signals a thousand times from 1MHz to 1kHz, pulling it out of the noise in the process. The software for this will be covered later but, at startup, it is a highly intensive task, best done in the 32-bit CPU. Once locked onto a satellite, it is repetitive and can be done in hardware or software. In this design, the 32-bit processor delegates it to the 16-bit slave.

The 16-bit Inmos T225 transputer has no floating point unit. It has the vital PCINT instruction that fortuitously allows the software processing of spread-spectrum single bit coded signals. But the real reason for its inclusion, rather than a 32-bit alternative, is its ability to work with byte-wide eprom and sram.

Two-wire serial links running at 20Mbit/s electrical rate handle input from the sampler and communication with the main processor. The circuit is shown in Fig. 6. There is a dual UART on the bus, which also provides the page register for the 128K x 8 eprom, too large to be addressed by the 16-bit CPU directly.

The 32k x 8 static ram retains battery backed information such as almanac and initial position between power-ups, while the PAL chip performs address decoding. Not shown in the circuit is a battery-backup control chip and lithium battery. The control chip hides in the address space of the ram, and ensures it is not accessed when the power is out of spec, and switches between main and backup voltage as appropriate.

**The main processor and framemstore**

The main processor is a T805 transputer, a 32-bit CPU with an on-chip floating point unit. In the demonstration unit, this module is an Inmos B437 transputer module, available off the shelf. It contains the T805, a G332 graphics chip, and 1Mbyte of video memory, which can be used for program, data and video-store as required. A block diagram is shown in Fig. 7, though this module provides far more video performance than required... it will drive 110MHz video systems: the PAL/NTSC compatible in-car monitor needs around 10MHz.

Thus a much lower cost video system has been developed, using three pal chips as counters to generate sync and blanking signals, and to signal the transputer’s link engine when a new raster line must be copied into the video ram internal shift registers. Thus without processor involvement, and without the problems of bus arbitration, video refresh is achieved. It does not have the flexibility of the programmable G332 solution, and cannot refresh the video ram serial port on-the-fly during a raster line, but it allows the main memory to be provided in low-cost dram, with just a single or dual video ram chip (Fig. 8).

Note that the transputer has an internal dram controller which provides timing and generates refresh. The only external chips required are those which separate the address/data bus, and multiplex the address for the dram. These tasks can be done in the same chips.

Output from the video system is RGB and sync on four separate coax connectors. These may be taken directly to a computer style monitor, or suitably coded for TV monitors.

**The map data store**

The map data store would normally be in an exchangeable plug-in memory card. However in order to remain compatible with the plug-in-module style of the design, an Inmos B418 flash eprom module has been used. This provides 256KByte of memory accessible down the transputer serial links.

The handling of map data is covered in a future article on GPS applications. Suffice to say here that the Ordnance Survey 250,000 scale maps, in vector form, may be pre-processed to obtain a complete 50km x 50km square into this amount of memory, complete with the names of every village, the outline of the built up land in the village, even of woods and forest. The processor can then display this to any desired scale from 10km across the screen to 50km.

In the demonstration version, I connect system to PC and load in data for the area required. In a production version, the user would remove the memory card and plug in another.

**The RGB to composite video encoder**

To use a low-cost volume product for the display, the video output is converted to television standards before passing to the monitor.

This is done with a Sony CXA1145 chip designed for the purpose. It needs only DC blocking capacitors, a colour burst crystal, a chrominance filter and a luminance delay line added to complete the circuit, and was again built on the module format. A pin selects between PAL and NTSC on the encoder chip, but ideally one would also change the filter and delay line to match.

The final output is a single coax carrying the luminance signal at baseband, with the line and frame sync signals coded conventionally as “blacker than black” levels. Colour is encoded as a colour burst before the video on each line, then quadrature signals on the colour sub-carrier at 3.58 or 4.43MHz.

*Philip Mathes is a consultant engineer working for Inmos, SGS-Thomson*

**Next month: radio hardware**
A UK-based research team is on the brink of a breakthrough in developing friendlier superconducting materials with higher transition temperatures. The team's discovery of a new ceramic material that becomes superconducting up to 92K is a significant step forward in the search that has been continuing apace since the Nobel-Prize-winning discoveries of 1986. The new material looks to be a promising candidate for a new generation of cables for power transmission.

Researchers from GEC and BICC, working at the Hirst Research Centre near London, reported the breakthrough earlier this year—a series of materials based on cadmium, lead and copper oxides promising superiority over known high-temperature superconductors in key areas of high-current applications.

Like most scientific work, the development actually comes after a long period of hard work—in this case two years' painstaking analysis, during which more than 15,000 material compositions were synthesised and characterised using a robot.

The breakthrough was helped by knowing where to look, based on the structures of known high temperature semiconducting materials.

The basic features are comparatively simple. Alternating layers of copper and oxygen atoms form conducting slabs, separated by insulating slabs formed of metal and oxygen ions. The conducting slabs are doped to produce charge carriers, with superconductivity arising when pairs of these carriers can move freely through the material without being scattered by the lattice. Because the interaction between carriers within the conducting layers is stronger than coupling between these layers, the pairs are effectively confined to their conducting slab. As a result, superconductors of this design are strongly anisotropic and electrical and magnetic properties are radically different parallel and perpendicular to the layer structure—though anisotropy can be adjusted by altering the properties of the insulating slabs.

Unfortunately, ceramics with this strongly anisotropic structure have important drawbacks for practical high-current applications such as transmission lines. One major problem is flux creep—the temperature-dependent wandering of lines of magnetic flux—severely limiting the superconducting critical current in high magnetic fields.

Well-known materials such as the YBCO 123 phase (YBa2Cu3O7-δ) show strong magnetic flux pinning at liquid nitrogen temperatures. But making use of this desirable property is difficult. Advanced material processing techniques must be used to form bulk polycrystalline conductors by aligning crystal grains biaxially, in a process known as texturing. A further challenge is to control the oxygen content and to prevent the superconducting phase deteriorating in the atmosphere.

Another well-known family of high temperature superconducting materials, known by the acronym BSCCO (Bi-Sr-Ca-Cu-O), overcomes some of YBCO’s problems, but does not perform well in high external magnetic fields or at high temperatures. Even small magnetic fields applied perpendicular to the copper-oxygen layers reduce its current-carrying capacity. Nevertheless, a great deal of effort has been put into developing manufac-
turing processes, such as the BSCCO-Ag tape process (filling a silver tube with BSCCO powder, drawing the material into wire, then applying a series of rolling and heat treatments). Significant progress has been made towards producing long superconducting tapes, but daunting challenges still remain.

**Lead cuprates**

Better electronic and magnetic properties are found with another family of materials containing thallium. Main problem with these is that thallium oxides are both volatile and highly toxic, and a key objective for the Hirst Research team was to look for thallium-free alternatives.

Promising candidates appeared to be lead cuprates, following the discovery of superconductivity in Pb2Sr2(1−x)CaxCu3Oy in 1988. Again, for developing practical superconducting cables, materials science considerations have been crucial. Much research has been focused on the (Pb, Cu)-1212 phase, as this is readily synthesised by conventional powder methods in an oxidising atmosphere. But its superconducting phase is complicated by a more orderly arrangement of oxygen atoms.

The theory is that the presence of copper within the lead-containing dopant layer leads to a random oxygen atom arrangement, trapping holes inside the layer and preventing them moving into copper-oxygen layers.

Another factor is the fixed valence state of cadmium, which along with the element’s structural preferences, helps to stabilise the oxygen content.

Confidence in this Cu-replacement approach was boosted by the fact that other researchers had already claimed success in creating bulk superconductors by replacing copper with calcium or strontium in the doped layer. Here again though, sample preparation involved an over-pressure of oxygen.

**Sample preparation**

In pursuit of the goal of producing superconductors readily in bulk, the Hirst team adopted a simplified approach to preparing their samples. Briefly, the process involves mixing solutions containing metal complexes with EDTA (ethylene diamine tetra acetate is a disolvate-all chelating agent), then evaporating off the water and decomposing the EDTA complexes by heating to 500°C in air. The resulting mixture of oxides and carbonates is ground and calcined at various elevated temperatures in the expectation of creating pure 1212 phases.

The purest phase of PCSYCCO, as identified by X-ray diffraction techniques, is obtained by dividing the samples finely and firing at between 750°C and 850°C. Powder X-rays indicate a tetragonal unit cell with a slightly shorter a-axis and slightly larger c-axis than the (Pb, Cu)-1212 phase, implying that cadmium ions fit well into the structure.

Samples show clear signs of superconductivity at 92K by the onset of diamagnetism, and by electrical resistance measurements. The relatively weak diamagnetism is equivalent to only a few percent of a perfect superconductor in the bulk sample, though this is partly explained by small grain size. Measurements show a distinct paramagnetic-to-diamagnetic phase change at 92K, though the electrical resistivity starts to drop at around 90K, but only reaching zero around 45K. The effect is thought to be a problem caused by the sintering process with lead-containing cuprates. Work is continuing to eliminate such shortcomings, for example by sintering the material under oxygen. Solving the problem

**Variation of magnetisation with temperature of (Pb0.5Cd0.5)Sr2(Y0.3Ca0.7)Cu2O7-δ. Both field-cooled and zero-field-cooled values were recorded.**

**Driving force for research into high temperature superconductivity is obvious.** The European Community estimates that resistive dissipation between power station and consumer is costing member states around ecu2.5 billion every year. That is a bill that would be dramatically reduced if traditional cables were replaced by superconductors operating at liquid nitrogen temperatures.

So there is plenty of motivation for the recently-reported work — a collaboration between GEC Aisbtom, BICC, ABB, Alcatel Cable, Pinelli Cavi and Siemens under the EC Brite/Euram materials and technology programme. The same companies are also studying techno-economic aspects of superconductor applications.
could lead to even-higher superconducting transition temperatures than those already obtained.

Meanwhile, the new superconducting material is being transferred to other collaborators in the EC Brite/Euram project, who will develop the processes required to turn the scientific discovery into practical superconducting cables. It may be a decade or so before this bears fruit, and as participants in the EC Joule project, the collaborators are also looking hard at economic feasibility. But positive results will not only be good news for power transmission, but also for future developments with the far-reaching possibility of no-loss energy storage.

Acknowledgements
This article was prepared with the help of D M Jacobson, M R Harrison and R Ghiggino at the Hirst Research Centre.

References

Operating at 77K, this experimental chip expander made with YBCO superconducting film is just a fraction of the size required by a conventional resonant cavity design. The superconducting microstrip allows an order of operating Q not normally associated with the technique.

Variation of electrical resistance with temperature of PCSYCCO.
Amplifier clip detector

Driving any power amplifier into clip soon proves fatal to loudspeaker drive-units. But the exact threshold of clip depends on output loading and mains voltage. Music signals are asymmetric, so bi-lateral detection is essential. The circuit provides true indication of clip irrespective of these variables by sensing the abrupt rise in feedback as the amplifier moves into clip.

The SSM 2017 true differential amplifier $IC_1$ reads the error voltage across the bases of the amplifier’s differential input stage. $R_1$ and $R_2$ stand-off the amplifier’s sensitive input nodes so stability is not affected by stray capacitance to ground. $C_1$ optionally prevents $IC_1$ responding falsely to VHF non-linearity.

In the linear mode, drive to $IC_1$ is close to 0V, rising sharply as the amplifier is over-driven. Unselected 2017s have appreciable DC offset, so $IC_1$‘s output is AC coupled ($C_2$, $R_3$), then fed to window comparator $IC_2$, which responds symmetrically to impulses greater than ±20mV, lighting the clip LED after integration ($C_3$, $C_4$). $R_3$ adjusts $IC_1$‘s gain in the region of x20 to x100. It is set on test such that the LED’s illumination corresponds to a given THD, or a threshold between, say, 0.1 and –0.6dB below clip. The monitor output feeds a scope or analyser for diagnostics.

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Current-to-frequency converter

As an alternative approach to the voltage-to-frequency converter circuit in which one resistor charges and discharges the capacitor, proposed by Trofimenkov et al in IEEE Trans. Inst. Meas., Sept. 1986, this circuit behaves also as a current-to-frequency converter in which pulse width/period ratio is a function of the input current.

When the output voltage of the 555 timer in Fig. 1 is high, $C$ charges through the operational transconductance amplifier, in which a slight voltage imbalance at its input causes all its bias current $I_g$ to flow in its load. This means that $C$ is charged by the constant bias current. At the two-thirds $V_{cc}$ point across the capacitor, the output voltage goes low and $C$ starts to discharge through $R$. At one third $V_{cc}$ on the capacitor, the output voltage again goes towards the supply and the cycle repeats. Since the input port of an OTA is a diode in series with a resistor, a voltage at the input will have the same effect as a current, so that voltage control is also possible. This circuit has been tested using a CA3080 OTA and a 555.

Muhammad Taher Abuelma’Atti
Dhahran
Saudi Arabia

February ELECTRONICS WORLD + WIRELESS WORLD
Schmitt-trigger VCO

One section of a 74HC14 hex. schmitt inverter makes a useful voltage-controlled oscillator.

When power is applied to the circuit of Fig. 1, point A is at OV and the inverter output is high. Capacitor C1 charges through R1 towards the input control voltage Vc, but, when it reaches the upper trigger level of the Schmitt Vt+, the inverter output goes low and discharges the capacitor through R2 and D1.

As a result, the voltage at point A drops, the cycle repeating when it reaches the lower threshold Vt-. At the output, a narrow, negative-going pulse appears, coincident with the "flyback" at point A.

Pulse width is dependent on the discharge current set by the value of R2 and the frequency on Vc, C1 and the hysteresis of the buffer.

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Programmable PWM

Intel's 8254 programmable interval timer contains three programmable counters, which may be made to perform the functions of programmable one-shot (mode 1) and square-wave (mode 3) generators, among others, by inputs to the D0-7 pins. In the application shown, the device is used as a programmable pulse-width modulator.

Two of the timers are used: timer 0 is programmed in mode 3 and timer 1 in mode 1, so that the output frequency is \( f_{\text{PWM}} = \frac{f_{\text{CLK}}}{2^n} \), in which n is the number programmed into the counter.

Pulse-width modulator, programmable in frequency and duty cycle, using two of the 8254's three counter/timers.

<table>
<thead>
<tr>
<th>F CLK</th>
<th>8254</th>
<th>VCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD0</td>
<td>8</td>
<td>D0</td>
</tr>
<tr>
<td>AD1</td>
<td>7</td>
<td>D1</td>
</tr>
<tr>
<td>AD2</td>
<td>6</td>
<td>D2</td>
</tr>
<tr>
<td>AD3</td>
<td>5</td>
<td>D3</td>
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<td>AD6</td>
<td>2</td>
<td>D6</td>
</tr>
<tr>
<td>AD7</td>
<td>1</td>
<td>D7</td>
</tr>
<tr>
<td>MA0</td>
<td>19</td>
<td>A0</td>
</tr>
<tr>
<td>MA1</td>
<td>20</td>
<td>A1</td>
</tr>
<tr>
<td>WR</td>
<td>23</td>
<td>G1</td>
</tr>
<tr>
<td>02XXH</td>
<td>21</td>
<td>OUT1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GND</td>
</tr>
</tbody>
</table>

Duty-cycle range is from 0 to \((2^n-1)\) so that if, for example, output frequency is to be 15625Hz and duty cycle range is \((2^n-1)\) or 511, the clock frequency is 8MHz.

The listing given here will do the job.

Shwang-Shi, Bai
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Linear swept VCO

A criticism levelled at conventional audio sweep generators is that no matter how pure the sine-wave from the VCO may be under static (non-swept) conditions, the picture changes when the VCO is swept. The following scheme, which uses a combination of sweep and burst techniques, is a way of overcoming this.

In essence, a staircase ramp generated with a clock, an n-bit counter and an n-bit D-to-A. The ramp is suitably scaled before being applied to the VCO. The output from the VCO is gated off for one cycle while it slews at each step in the ramp. A positive transition of the clock sets FF₁. On completion of the current cycle from the VCO the zero-crossing detector produces a positive edge which resets FF₁. The positive edge from FF₁ now clocks the counter and sets FF₂. Q₂ inhibits the output. The D-to-A output increments to the next staircase level. At the end of the next cycle (distorted as it slews) the zero-crossing detector resets FF₂. The output inhibit is removed and the circuit produces a burst which lasts until the next clock pulse whereupon the above action repeats.

The output therefore consists of bursts of undistorted and complete sine-waves, the frequency of which increases with each step of the staircase.

References

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Asics

200MHz FPGAs. AT&T's ATT3000 series of field-programmable gate arrays now run at 200MHz - a performance attributed to the use of the company's 0.6µm silicided cross process. Devices toggling at 230MHz are expected in production early in 1993, AT&T Microelectronics, 0344 865927.

ASIC libraries. The Liberty series of physical layout libraries and compilers from Compass allows a designer to choose the foundry and cross process for production. As well as working with the Compass Navigator system, the series supports a variety of design tools such as Mentor Graphics, GenRad and Zycad. The library includes gate array and standard cells, and ram and multiplier compilers and the Compass Datapath compiler. Compass Design Automation, 0908 661729.

0.8µm gate arrays. Four new devices have joined Hitachi's H662G gate array family. Gate counts now reach 54202, 51100 and 70500, with I/O of 264, 288 and 336. The fourth device is for smaller applications and contains 10000 gates with 136 I/O pads. The H662G family offers sub-nanosecond operation (0.3ns for a 2-input power NAND) and operates from 2.7V to 5.5V rails. Harris Semiconductor (UK) Ltd, 021 6999.

Discrete active devices

Fast-recovery mosfets. ABB-IKYS HypeFET mosfets allow the use of the ABB-IKYS intrinsic diode in free-wheeling applications due to its fast reverse recovery, which is 60% faster than standard mosfets with no increase in on resistance. The one intrinsic diode eliminates the series schottky and parallel diodes. The range includes 75A/100V/0.02µs up to 12A/1000V/0.05µs all with a reverse recovery time of less than 250ns. Kudos Thame Ltd, 0734 361010.

Digital signal processor

Histogrammer. Harris's HSP48410 is described as a histogrammer/accumulating buffer and is designed for extremely accurate histogram calculation and image contrast enhancement in machine vision systems, target recognition and medical imaging. It will evaluate contrast in images of up to 4096 by 4096 pixels and generate a histogram of input gray levels for manipulation or analysis, the data being used to modify or enhance the image. Harris Semiconductor (UK) Ltd, 0276 699886.

Linear integrated circuits

Video amplifier. Comlinear's CLC411 is a 200MHz video op-amp intended for HDTV, composite video, line, driving and D-to-A output buffering. Slew rate is 2300V/µs with a settling time to 0.1% of 15ns. To 33MHz, gain varies less than 0.05dB and diff. gain and phase are within 0.02% and 0.03% respectively. The device has fast, break-before-make enable and disable. Joseph Electronics Ltd, 021 643 6999.

Zero-drift op-amp. Linear claims its new LTC1250 chopper-stabilised op-amp to be the lowest-noise device of its type available. From 0.1Hz to 10Hz, noise is 0.655V p-p in the presence of a 4.2V output swing into 1kΩ. Sample-and-hold capacitors are on the chip. Particularly useful for bridge transducers, there is only 50V. C. Offset drift and maximum offset is 10V/µT. Linear Technology (UK) Ltd, 0276 677676.

Dual quad op-amps. LT1124 dual and quad op-amps from Micro Cali are claimed to exhibit the lowest offset voltage of any such non-chopper stabilised amplifier available. Typical and maximum figures are 20µV and 70µV, both with a maximum drift of 0.5V/µs. Input bias and offset currents are both 250pA. Voice performance of both devices between 0.1Hz and 10Hz is 0.32µVp-p and slew rate is 0.3V/µs. Micro Cali Ltd, 0844 261939.

Triple video amplifier. Elantec's EL4390 consists of three 60MHz current feedback amplifiers, each with a DC-restored amplifier activated by a common TTL/CMOS-compatible control signal and each having a separate restore reference. Response is flat to within 0.1dB to 10MHz and slew rate is 900V/µs. Microelectronics Technology, 0844 278781.

FM paper receiver. Philips claims its UAA2060 to be the most advanced single-chip direct-conversion FM receiver for pager, when used with the PC50501T decoder, the result is a two-chip wide-area beep-only pager or a high-performance display paper front-end. The chip receives and demodulates FM NRZ-FSK data, operates up to all at 512MHz with a sensitivity of -124dBm for a bit-error rate of less than 3/100. Active and standby currents are 2.7mA and 3µA, Philips Semiconductors Ltd, 071 436 4144.

Complementary mosfet arrays. Complementary mosfet pairs in the same package from Zetex feature a 60V maximum drain/source voltage and a peak current rating of 3A. The ZVC2016E handles 280mA continuously and has a gate/source threshold of 3.5V at 1mA, with an on resistance of 51Ω at 10V and 500mA. Zetex p.c, 061 627 4963.

Logic building blocks

Character display. Two ICs from Philips, the PC88510 and PC88516, are designed to generate on-screen characters for television displays and camcorders, being the first to incorporate software half-tone colour control to enhance readability. They will show a full screen of up to 13 or 40 lines of 36 or 40, 12 by 18 characters, depending on the television standard. Philips Semiconductors Ltd, 071 436 4144.

Memory chips

4Mbit eproms. AMD has announced the Am27C4296 and Am27C4200 devices, the former being organised as a 256k by 16bit type and the latter a rom-compatible cmos device user-configured as 512k by 8bit or 256k by 16bit eprom. Both are in 0.85u cmos and possess an access time of 120ns. Advance Micro Devices UK Ltd, 0483 740440.

4Mbit word-wide drams. Hitachi's second generation of devices, the HM512A6204 256k by 16bit type and the HM512A6240 256k by 18bit unit are dynamic rams in 0.7µ cmos, with access times down to 70ns. The 60A
uses only 825mW when active, reducing to 1.1mW from 5V standby. Hitachi Europe Ltd, 0262 585000.

**Mixed-signal ICs.**

**Electronic digital pot.** From Dallas, the Dallasast DS1668/1669 is a digital interface and non-volatile memory, forming an alternative to mechanical potentiometers. DS1668 has a manual interface and the 1669 is configurable for two-button operation, both types being digitally controlled by means of the interface. The memory retains last setting when power is removed. Values are in three ranges up to 10K, 50K and 100K. Joseph Electronics Ltd. 021 643 6999.

**Distance sensor.** The GP2D02 distance sensor by Sharp contains an infra-red led, a position sensor and signal-processing to measure distances up to 100cm, 30cm or 10cm-80cm, depending on the version. Output is in the form of an 8-bit code. Current consumption is 7mA or 4.5mA, dropping to 2mA in the absence of a reflective object. Sharp Electronics (Europe), 010 49 40 23 76-0.

**Optical devices.** Bright, blue leds. Sharp's GL584X3 silicon carbide light-emitting diode has a luminous intensity of 16mCd at 20mA, emitting at a wavelength of 470nm and a bandwidth of 70nm. Sharp points out that RGB displays using leds are now possible. Sharp Electronics (Europe), 010 49 40 23 76-0.

**Power semiconductors.**

**Switching regulator.** Two 200kHz current mode switching regulators by Linear provide 1% regulation and stabilisation with no opto-coupler for feedback, power transmission and secondary sensing. Being done via the transformer, LT105 has a totem-pole output to drive an external fet, while LT103 has its own fet output, the former being designed for 50W-250W output and the latter for 10W-100W operation. Linear Technology (UK) Ltd. 0276 677676.

**2kV linear amplifier.** A 2000V linear amplifier by Apex, the PA30, produces up to 8kW pulse output and the 2kW continuous from zero to 40kHz. Output current is 50A continuous (100A pk) on rail-to-rail supplies of up to 200V. Power mosfet outputs avoid secondary breakdown and on-chip sensors provide thermal protection. The package measures 2.8 by 2.2 by 0.4in. Microelectronics Technology, 0844 2787871.

**Power mosfets.** APT10050JN is an n-channel 1kW power mosfet from APT, rated at 520W dissipation and packaged in SOT-227. The single die is rated at 20A, with a drain-source on-state resistance of 0.5Ω, meeting 2 5kV RMS isolation. Microelectronics Technology, 0844 2787871.

**Regulators.** Sharp’s PQ series of voltage regulators drops only 0.5V from input to output, reducing power loss and therefore the need for large heat sinks. Output current is up to 2A; regulation is 0.2% for a 2000-fold load current increase and stabilisation gives a 0.4% output voltage change for a two-fold input change. Sharp Electronics (Europe), 010 49 40 23 76-0.

**DIP power.** PowerLogic is a new range of TI peripheral drivers in dip packages—the first to combine power transistors and cmos logic on the same substrate. TPIC2595 is an 8-bit addressable latch; TPIC6753 an octal D-type latch; and TPIC6595 an 8-bit shift register, all working in the range +40°C to 125°C. Texas Instruments Ltd, 0234 223252.

**NEW PRODUCTS CLASSIFIED**

**NEW PRODUCTS CLASSIFIED**

**Power in VA.** Mathematical facilities measure alternating and direct voltage and current, frequency and phase separation. As video and sound quality monitor, it reproduces on screen a zoomable picture, with the input signal and line trigger. It will also operate as a spectrum analyser. Feedback Instruments Ltd, 0892 653322.

**Passive components.**

**Tantalum chip capacitors.** Capacitors in Murata's 227 range measure 1.2mm in height and have a range of values from 0.1uF to 6.8uF in voltage ratings of 4.5-20V DC. Leakage current is less than 0.4pA at 25°C. Murata Electronics (UK) Ltd. 0252 811666.

**Connectors and cabling.** 2mm IDC connectors. Cambion has the 2630 series of insulation-displacement sockets and headers in straight and right-angle form for termination of 1mm 28awg ribbon cable. Current capacity is 1A per line. These turn-on-contact sockets with a basis to retain the cover come in 12 to 50-way versions and offer a contact resistance of 20mΩ and insulation resistance of 10GΩ. Interconnection Products Ltd. 0433 21555.

**Tough microwave cable.** Internally strengthened microwave cables from Gore are small in diameter, low in weight and flexible, but withstand 175°C linear inch, which means they will take the weight of a forklift truck, should the occasion arise. The cables have Gore-Tex expanded PTFE dielectric, giving a temperature range from -200°C to 200°C. A range of connectors is available. W L Gore & Associates (UK) Ltd. 0382 561511.

**EMC shielding.** Econoshield is RF Shielding's new material for the commercial sector where low compression force is needed—round doors, for example. Shielding is effective between 30MHz and 1GHz, providing around 30dB attenuation. The material consists of polyurethane foam covered by a layer of Monel wire, available in a variety of cross-sections, most being available with a pressure-sensitive adhesive backing. RF Shielding Ltd. 0375 342626.

**Passive**

**Passive components.**

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**Filters**

**Chip EM filter.** Murata's NFMS1-S9R EM filters offer 100dB/decade damping and are intended for use with digital circuitry, eliminating noise from clock and video RGB circuits or that from DSP and image processing equipment. Four cut-offs are available: 50MHz, 100MHz, 200MHz and 500MHz, suppression at 50GHz still being about -40dB. Murata Electronics (UK) Ltd, 0252 811666.

**Hardware**

**Rectangular feedthrough.** Possibly the first mass-produced rectangular feedthrough capacitor is produced by Beck. It measures 4.9 by 4 x 2.7mm and was designed to fit over the rectangular 30A pin of a car component. Values of the ceramic capacitors is 100pF at 100V DC. Beck Electronics Ltd. 0493 856282.

**RF seals.** Conductive, elastomeric materials for Anti-EMI sealing from Dunlop have been tested to US military spec MIL-G-83526A. The new materials are based on silicone and fluorocarbon rubber with metallic or metal-coated fillers and reinforcements such as metalised fabric, which offers a 0.0016cm resistivity. These materials will attenuate frequencies up to 18GHz by up to 100dB. Dunlop Precision Rubber, 0509 502511.

**Infra-red pocket boxes.** Hand-held boxes designed to hold IR circuitry for signalling or remote control by OKW are said to be the only ones available with IP65 sealing and battery compartments. They are made in polycarbonate and ABS in three sizes and a belt clip as an option, as is machining and silk screening to order. OKW Endosystems Ltd. 0489 583858.

**Instrumentation**

**Measuring receiver.** ITT's VX600S TV measuring receiver copes with satellite and FM ranges, meeting European standards for to monitor, video modulation and video sound separation. As video and sound quality monitor, it reproduces on screen a zoomable picture, with the input signal and line trigger. It will also operate as a spectrum analyser. Feedback Instruments Ltd, 0892 653322.

**Wider-range sig gens.** Hewlett-Packard has expanded the frequency range of its HP70341A 10MHz-1GHz unit. Modulation is 60dB log. AM, 10MHz peak RM deviation and pulse modulation with less than 10ns rise and fall times. Frequency modulation is 1kHz, or 1Hz as an option. Hewlett-Packard Ltd. 0344 362867.

**Digital multimeter.** Saje's 7130 bench multimeter is programmed via clock and video RGB circuits or with digital circuitry, eliminating noise from clock and video RGB circuits or that from DSP and image processing equipment. Four cut-offs are available: 50MHz, 100MHz, 200MHz and 500MHz, suppression at 50GHz still being about -40dB. Murata Electronics (UK) Ltd, 0252 811666.

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difference, maximum/minimum and relative; these being intended to ease production batch testing. Sage Electronics, 0232 425440.

TV signal-level meter. Leader's model 952 multi-channel television and satellite signal-level meter is programmed to cover VHF/UHF television and CATV as well as satellite channels. It can cover up to 128 channels simultaneously, with a bar-graph display automatically scaling to respond to both smallest and largest signals in a group. Both sound and vision carriers are displayed and the instrument stores in non-volatile memory four sets of eight channels, channels from any band being shown together. Thurlby-Thandar Ltd, 0480 412451.

Literature

Sensor handbook. Piezoresistive silicon pressure sensors and transmitters, with application notes on signal conditioning and interfacing, are all described in a new handbook from Sensortechnics in Puchheim, Germany. Sensortechnics GmbH, 010 49 98-80 08 30.

Materials

Ceramic HV capacitors. A range of capacitors from the Cera-Mite Corp. handle up to 13kV RMS at 60Hz, using a new ceramic material. Capacitance values are 400pF to 4700pF working at 10kV DC/4kV RMS at 60Hz to 40kV DC/13kV RMS at 60Hz. The material in the KT series was introduced by Cera-Mite, a Sil-cone technology, offering a reduced backup time and reduced board space. The AC300 or Ace Caps work in the -20°C to 70°C temperature range. Surtech Interconnection Ltd, 0256 51221.

Battery protection. TI has the 4MM - a bimetallic protector for rechargeable batteries. It guards against both thermal overload and short circuits, replacing the two circuit components normally used. Texas Instruments, 0224 223252.

Radio communications products

Linear amplifier. AML's new APO1501640 1.5-16GHz linear power amplifier provides a 16W output with a gain of 22dB, flat to within ±0.2dB. A feature is gate current monitoring to achieve enhanced reliability. European Microwave Components, 0376 515200.

Telemetry RX module. SLRX-418-A is a sil-cone UHF radio telemetry receiver module made by Radiometrix. It is meant for use with the TXM-418-A transmitter module, in low data rate paging applications and is a PCB-mounted 418MHz receiver, needing only an antenna. The double-conversion FM superhet and data slicer driven by the AF output will drive a digital decoder for secure links. Maximum active-mode current is 15mA - 130mA when on standby. Quatelec Ltd, 0993 776488.

Radio data link. A range of UHF communications equipment by Wood & Douglas is intended for remote outdoor use. The SurTel data link provides simplex or semi-duplex communication over a 20km line-of-sight range. Internal modems transferring data at 1200 and 2400 baud. The required supply is either 12V DC or mains and a standby circuit maintains only the oscillator in operation, thereby ensuring minimum frequency drift with a short power-up delay. Wood & Douglas, 0734 811444.

Power supplies

Programmable PSU. Thurlby-Thandar offer the TSF3222, a dual programmable power supply intended as both bench unit and as part of an ATE system. Outputs are both 0-32V, 0-2A, independent and isolated to 300V. Both operate in constant-I or constant-V mode with automatic crossover and switching of the display from current to voltage. A GPIB interface is fitted and a LabWindows device is an option. Feedback Instruments Ltd, 0892 653332.

Memory protection. Double-layer capacitors from Surtech are small and light alternatives to the batteries usually used for memory protection, offering a reduced backup time and reduced board space. The AC300 or Ace Caps work in the -20°C to 70°C temperature range. Surtech Interconnection Ltd, 0256 51221.

Multi-functional measurements. Scopemaster from Thurlby-Thandar is a combined oscilloscope, counter-timer, da, an analyser and multimeter in one case, the whole costing £450. The dual-channel digital storage oscilloscope has a 20MHz bandwidth, sampling at 20Msamples/s, with a repetitive mode to 2.5ns resolution. There are for waveform stores and a printer output. All the separate instruments use the oscilloscope's 3in LC screen and the whole thing is battery-powered. Thurlby-Thandar Instruments, 0480 412451.

Switches and relays

Low-noise relay. CRX-12X from BL is a relay designed for the car industry, having a low level of acoustic noise (60dB(A)) so that intermittent windscreen wipers, for example, do not cause too much of a racket. It has silver alloy contacts and operate and release times of 1ms and 2ms respectively. BL Components Ltd, 0638 665161.

Product labels. Info-mark and Appliance-mark by Donprint are label-printing devices, using on-screen design and 300dpi dot printing on material capable of withstandng temperatures up to 380°C and a variety of cleaning materials including petrol, detergents and some fairly hostile chemicals. Donprint Label Systems Ltd, 0355 249191.
Miniature RF relay. A 12V miniature PCB-mounted RF coaxial relay marketed by Crikil will switch up to 50W CW at 1GHz, with a maximum insertion loss of 0.3dB at 1.8GHz and an SWR of 1:1.3 at 1.8GHz. Line impedance is 50Ω and contact form is single-pole changeover. Crikil Distribution Ltd, 0922 44011.

PCB connector. A surface-mounting, dual-row inverse connector from Methode has an off-the-board height of 2.7mm. It comes with vertical holes and the other with horizontal holes for inserting from either side, both having from two to forty positions on each row at 0.1in pitch. Contacts handle up to 3A. Methode Electronics Ltd, 0535 600292.

PCB switches. A new family of sub-miniature switches by Elma, the Type 09, are meant for PCB mounting or for through-panel use. Either toggle or push-button variants are made, the toggle type with two or three positions and the button type in latching or momentary contact form, with the option of illumination. Radiatron Components Ltd, 081-891 1221.

Transducers and sensors

Miniature gyro. Murata's ENC-05S gyrostabil is a miniature version of the company's triangular piezoelectric vibration control system, which uses one prism to increase sensitivity by 100 times compared with a tuning-fork type. The triangular structure overcomes the vulnerability to vibration suffered by earlier designs. Bandwidth is 50Hz, the maximum angular velocity of ±90°/s producing an output of 10mV/g.

Position transducer. Rayelco Magnetek use the extension of a miniature position transducer by Position transducer. Rayelco Magnetek use the extension of a miniature position transducer by

Development and evaluation

P1C15X00 emulator. Running on PC 286 upwards, Microchip's PICmicro universal in-circuit emulator now handles the company's P1C16X00 range of microcontrollers, the industry's only 8-bit iso family. It will support different family members by means of a probe card change. Arizona Microchip Technology, 0298 850303.

Universal programmer BP-1200 from BP Microsystems Inc. is claimed to be the first programmer capable of programming and testing up to 240 pins in DIP, PLCC, LCC, QFP, PGA, SOIC and TSSOP packages. Atten has been paid to the reduction of ground bounce, so that the units cope well with fast cmos PLDs and FPGAs. Direct Insight Ltd, 0455 558564.

Image compression. The JPEG image-compression board for PCs by C-Cube Microsystems is now available in Europe. It is an ISA half-card running at 10MHz and supporting grey scale, YUV (4:2:2 and 4:4:4), CMYK and 24-bit RGB. Data compression rate is more than 1Mbyte/s, allowing the unit to compress or decompress a 24-bit, 640 by 480 image in 0.75s on a 386SX. The still-image development kit includes schematics, PAL equations, BMP-compatible link library source and full documentation. Kudos Thame Ltd, 0734 351010.

Eeprom emulator. Optocron from Ransomes will emulate 8-bit eeproms from the 27C16 to the 27C3208 without hardware upgrading, and handles eeproms in 16 and 32-bit mode up to 4 by 4bit using an add-on board. Data can be downloaded from the serial port of a PC at 115Kbaud in binary, intel-hex, Tektronix and Motorola formats over a high-speed opto-isolated RS232 link. Logcom Communications Ltd, 081 756 1284.

TurbO debugger. ChipView-51 is Nohau's new C source-level turbo C debugger for the company's range of EMUL51-PC in-circuit emulators, compatible with the Borland turbo debugger. The unit provides up to 16K source lines using the standard analogue, digital and timing I/O. Three multifunction boards from National for the PC offer analogue, digital and timing I/O data acquisition. AT-MIO-04F-5 has 64 single-ended analogue inputs to 12 bits, eight TTL digital I/O lines, three counter timers and 16-bit DMA, all at 200kHz. AT-MIO-16X has similar facilities, with a 16-bit sampling ADC and AT-MIO-16D a 16-bit A/D. National also has the Lab-PC+, an improved version of the Lab-PC providing differential inputs. An increase in cost. National Instruments Ltd, 0800 880000.
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Fuzzy logic de-fuzzed

It must puzzle people wanting to buy a washing machine to discover that it not only washes cleaner, but uses fuzzy logic to do it; fuzziness is not normally a characteristic of logic. Ross Bannatyne of Motorola in East Kilbride has written a note, DC410, to dispel the haze which still exists among engineers.

Bannatyne explains the principles behind the sudden popularity of fuzzy logic: that it is an intuitive method of describing complicated problems in terms such as “fairly hot” or “fast”, with no need to be adept at programming; and that it is a powerful, non-linear and efficient way to map outputs to inputs using a small amount of code.

A classic control problem, for example, is the inverted pendulum in Fig. 1. To keep the pendulum upright, one has to apply a voltage to the trolley’s motor to move it in the same direction as the pendulum, using the angle of the pendulum and the rate of change of that angle as inputs. Four second-order differential equations would normally be needed to solve the problem, which would need a 32-bit floating-point processor.

Fuzzy logic embedded software will do the job with a 2MHz 68HC11. An even more compelling point is that the use of fuzzy logic can shorten development time by up to 90% in some cases and will certainly reduce the size of required memory – lookup memory does not assume the importance it does in conventional techniques of input/output mapping.

The two diagrams in Fig. 2 illustrate the way in which relatively imprecise descriptions can be made more precise than exact ones. In the left-hand diagram, “1” and “0” qualities describe whether one is old or middle-aged, so that one is either one or the other and an intersection of the areas would not give much more information except to indicate that one was on the borderline. On the other hand, the fuzzy descriptions show that a 48-year-old is 80% middle-aged and 20% old.

Figure 3 shows the fuzzy procedure in broad outline. The first block “fuzzifies” the input, converting input values to the amount to which they belong to one of the sets allotted to describe them, or their degree of “membership”. An “expert” knowledge defines the limits and degrees of membership; for example how hot is “hot” in a furnace or how fast is “fast” in an engine. The advantage here is that to get to the final solution one has simply to tune the degrees of membership.

In the second block, rules are applied, these rules being written in “fuzzy inference” language such as if-AND-THEN. if, for example, it is “cold” outside AND it is “not very warm” inside, THEN turn the heating on.

Lastly comes de-fuzzification to give a definite output.

Motorola Ltd, European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP.
DC-to-DC converter transistors

Note AN81 by Zetex describes use of the company's hi-rel range of E-line bipolar and mosfet transistors in DC-to-DC converters, providing up to about 10W for small equipment such as fluorescent tubes and flash guns.

With high current capability, these devices will easily function in a single-transistor converter such as the 8W fluorescent lamp inverter in Fig. 1. Such a load comes well inside the "awkward" category, since it needs a high voltage to strike, whereupon if promptly becomes a low-impedance load, taking up to about 3A for this size of lamp. Instead of an expensive T0220 kind of device, the Zetex E-line ZTX652 will handle the variable load, supplying the current without needing a high \( V_{CEO} \).

Figure 2 is a minimal converter giving +12V and -5V for memory, interface and display circuits from a 5V supply. Two ZTX449s working at 25kHz have to supply up to 1.5A peak at \( V_{CEO} \) of 250mV to give decent efficiency from 5V.

Capacitors are another type of difficult load since, in a typical flashgun for example, the voltage across them varies from 0 to 400V during the charging cycle. A flyback converter to isolate the load from the switching circuit is one answer and Fig. 3 is an example, the higher peak switching current needed in a flyback converter over a forward converter putting the high current and low saturation voltage of these transistors to good use. A shutdown sensor avoids output \( C \) overcharging and increases battery life.

Zetex plc, Fields New Road, Chadderton, Oldham OL9 8NP. Tel: 061 627 5105.

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**Fig. 1.** Single-device 8W converter for a fluorescent tube, using Zetex E-line ZTX652, which passes high current at low saturation voltage.

**Fig. 2.** 5W converter for memories and interfaces, powered by a 5V supply.

**Fig. 3.** Flyback converter for a flashgun. Shutdown sensor conserves battery and protects output capacitor.
Stereo D-to-A converter

Crystal’s CS4328 is an audio stereo digital-to-analogue converter for digital audio which contains, in addition to the D-to-A function, an eight-times digital interpolation filter and a 64x oversampled delta-sigma modulator to control the reference voltage to an ultra-linear analogue low-pass filter, allowing adjustment of the sample rate between 1kHz and 50kHz simply by changing the clock frequency while maintaining a linear phase response.

Figure 1 shows a typical application circuit and Fig. 2 the sequence of operations. Audio first sees the digital interpolation filter, which takes out images of the input signal at multiples of the sample frequency Fs of less than eight times. This leaves multiples of 8 x sample frequency and reduces filtering requirements, leaving the audio band intact, as in Fig. 3. Then comes a sample-and-hold stage in which data points from the interpolator are held for eight clock cycles (64xFs). The response is a sinx/x shape with zeros at 8 Fs multiples, suppressing the 8xFs signals and getting rid of much of the energy surrounding them, as in Fig. 4. The result of all this as data at a rate of 64 Fs.

In a 48kHz sampling system, the delta-sigma modulator receives data at 3.072MHz and carries out fifth-order noise shaping, allowing 1-bit quantisation to support 18-bit processing by suppressing quantisation noise.
in the relevant bandwidth.

A D-to-A now translates the 1-bit signal to a series of charge packets, the magnitude of each determined by sampling a reference to a switched capacitor where the polarity of each packet is controlled by the 1-bit signal. This system is insensitive to clock jitter.

Analog-to-digital filtering consists of a switched capacitor low-pass and a continuous-time type. Fig. 5 showing the output of the S-M type and that of the second filter.

An evaluation board from Crystal carries the CS4328 and a CS4312 digital audio receiver, taking data from AES/EBU, and providing timing for the CS4328. Figure 6 shows its block diagram.

Note CS4328 by Crystal Semiconductor Corporation, which is available here from Sequoia Technology Ltd, Unit 5, Bennet Place, Bennet Road, Reading, Berkshire, RG2 6QX. Telephone 0734 311822.
Analog Electronics
Ian Hickman
Good all-round electronics designers are hard to find, according to the recruitment specialists. There are either bad all-rounders or good specialists (for example, microwave, power supply, microprocessors specialists). Many young designers have been lured away from the fundamentals of electronic design to more "glamorous" digital work, yet there are many simple pieces of electronic equipment for which a purely analogue realizatiun is still cheaper, more reliable and more appropriate than a microprocessor-based solution. Analogue staff are in desperately short supply, and in many fields telecommunications for example - analogue skills are very much in demand. Ian Hickman's latest book includes many examples from his large collection of circuits (built up over thirty years in commercial, professional and defence electronics), selected for their usefulness in a wide range of applications. Hardback 300pp. Price £32-40

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Price £15-95

Books published by Butterworth-Heinemann
Self-calibrating noise source using silicon

Modern semiconductor noise sources for testing communications equipment need calibrating by the manufacturer. As a result, they are too expensive for many people. T H O'Dell describes a novel way around the calibration problem.

In the past it was possible to obtain temperature limited thermionic diodes suitable for use as self-calibrating noise sources in the HF and VHF bands.

Writing in 1982, Jessop may well have been the last author to describe such a noise generator. He gave a detailed design, based on Fig. 1, involving a diode with a plain tungsten filament fed by a variable 0–6V supply. To provide the source impedance needed for HF and VHF receiver noise measurements, the diode passed its anode current into a 75Ω resistor R."n.

As Fig. 2 shows, the thermally limited anode current, IA, of such a diode varies with anode voltage, VA. In such a thermally limited diode, there is a wide-band noise current superimposed on the anode current with a mean square value

\[ \overline{I^2} = 2eB \]  

where e is the electron charge, 1.6 x 10^-19C, and B is the system bandwidth in hertz. The noise generator of Fig. 1 is connected to the receiver input which is matched to Rs. As a result, noise power delivered to the receiver must be

\[ P_n = \frac{\overline{I^2}}{4} R_s \]  

There is also the maximum available noise power generated by the source, Rs, because of its finite temperature, T. This is well known to be kTB, where k is Boltzmann's constant, 1.38 x 10^-23J/K. Ideally, this unavoidable noise power from input termination Rs would be simply amplified by the power gain of the receiver, G, appearing at the output as kTBG. However, practical receivers are not ideal and produce more noise output power than this.

To indicate how closely the receiver approaches the ideal, the concept of noise factor, F, is introduced. Writing the noise power actually measured at the receiver output as,

\[ P_n = kTBFG \]  

it is clear that an ideal receiver would have an F of unity. In practice a good HF or VHF receiver will have a noise factor of about two. The information box “Measuring receiver noise” discusses how noise sources are used.

Semiconductor noise sources

The beauty of the thermionic diode noise generator was its self-calibrating nature. Its shot noise current was given fundamentally by equation one. Now however it has now fallen out of professional use, being replaced by far more reliable, and much wider bandwidth, solid state noise sources incorporating avalanche diodes. These are quite expensive and must be calibrated. The manufacturer measures the absolute noise power output of the source and provides the information with the product, usually as an equivalent noise temperature or an excess noise ratio expressed in decibels.

Commercial solid-state noise sources are outside the budget of many. It would be nice if there was a modern solid state replacement with the same self-calibrating feature as the old thermionic diode. My proposal, shown in Fig. 3, is essentially a photodiode illuminated by a simple filament lamp. Comparing Figs. 2 and 3, it is clear that both devices share the same very high impedance characteristic, with the photodiode having the great advantage of working at a much lower voltage.
Both devices also share the same fundamental shot-noise component:

\[ \dot{I}_n = 2eI_A R_S \]

for the thermionic diode and

\[ \dot{I}_n = 2eI_R R_S \]

for the photodiode.

Unfortunately, for sensible levels of illumination, the photodiode can only provide reverse currents up to about 100µA. As the first equation in the panel shows, when \( R_s \) = 75Ω, anode current will need to be a few milliamperes if noise factors as high as two or three are to be measured.

Figure 2 shows that a maximum anode current of 10mA would be ideal, which means that the photodiode fails short by a factor of 100 as a direct replacement for the thermionic diode. In all other respects however the photodiode looks well worth considering. Its power supply problems are trivial and its high frequency performance should be excellent.

High-speed diodes, like the Hewlett-Packard 5082-4220, or the readily available BPX65 can be relied upon to give a shot-noise current up to several hundred megahertz.

Making the impedance that the photodiode drives a hundred times bigger overcomes its shortfall in current capability. This calls for an impedance transformation of 100:1 between the photodiode and \( R_s \), the output impedance of the noise generator. Of course an impedance transformation of 100:1 calls for a 10:1 transformer, and it is just not possible to realise this over a wide RF bandwidth. On the other hand, a narrow-band 10:1 transformer is a simple design problem.

Three possible ways of solving the design problem are shown in Fig. 4. In all three cases, a high-Q resonant circuit couples the photodiode, represented by the current generator, to the low impedance output socket. In Fig. 4(a) a resonant transformer is used, in (b) the impedance transformation is effected by making the tuning capacitor act as a potential divider, while in (c) a tapped inductor is used. In all three cases additional damping is provided by resistor \( R \) to make the output impedance of the noise generator 75 or 50Ω as required.

Although described as narrow-band, the impedance transformation will have a bandwidth much greater than the bandwidth of the apparatus being tested. A communications receiver usually has an overall bandwidth below 10kHz. Whereas the photodiode noise generator has a bandwidth of more than 100kHz.

Initially when using a thermionic diode noise generator the filament is cold and anode current is zero. The only noise output power should be \( P_{out} \), given by equation three in the main text. Great care must be taken to isolate the receiver being measured from unwanted signals.

A relative indication of noise power can be obtained by simply measuring the RMS voltage across the receiver audio output. Of course the receiver must be working at such a low level input that its AVC has no effect, otherwise it will be non-linear and none of the simple linear theory being used here applies.

Diode filament voltage is then increased, causing anode current to rise, until noise output power from the receiver is just doubled. When this is done, \( GP_n \) must be equal to output noise power \( P_{out} \) given by equation three in the main text; receiver input noise power \( P_i \) is given by equation two.

Writing this equality down, substituting equation one and re-arranging provides the well known result for the noise factor:

\[ F = 20 \log_{10}(F) \]

when \( R_s \) is at room temperature, 290K, for which \( kT \) has the value 25mV.

Similarly, noise factor is measured using the photodiode source by connecting it to the receiver and first measuring noise power output with the lamp off. Supply voltage to the lamp is then increased until the noise output power is doubled. At this point the value of the photodiode current, \( I_R \), is noted.

Following the same argument that led to the previous equation, noise factor \( F \) is given by 2000\( R_s \), where account is taken of the 100:1 impedance transformation. Usually, the noise figure is quoted in decibels which is related to the noise factor by

\[ F_{dB} = 10 \log_{10}(F) \]

Noise in decibels as a function of photodiode current for source resistance values of 75 and 50Ω is shown in the first plot. Effective input noise temperature, \( T_{in} = 290(F-1) \), is also scaled to the right. Since noise in modern communication systems can be very small indeed, expressing noise in this way is becoming more popular than the straightforward noise figure.

As this is a relatively narrow band noise source it is vital that measurements are made as close to the centre of its operating bandwidth. In the second graph, you can see that this is easily checked by making a few measurements across the band.
RF ENGINEERING

Fig. 4. Matching a photodiode noise source to a receiver's input needs an impedance transformation of 100:1, which is impossible to realise over a wide bandwidth. These three high-Q narrow-band circuits all solve the problem but (c) has the advantages of easy implementation and low component count.

Fig. 5. Practical noise source for the 28MHz band. In common with most RF measurement equipment, this circuit needs careful construction but unlike avalanche-diode equivalents it avoids expensive calibration.

Fig. 6. This photograph of the author's prototype shows how connections are soldered to the lamp to avoid contact noise.

All three methods of impedance transformation shown require good RF voltage and impedance measurement facilities to verify the design. The tapped inductor of Fig. 4(c) is the least demanding however and also involves least components.

Applying the design

Figure 5 shows the circuit of a photodiode noise generator for use in the 28MHz band which has been built by applying the ideas discussed. Figure 6 is a photograph of the actual hardware.

Inductor L is a low capacitance, high Q coil comprising 10 turns of 0.85mm (20SWG) copper wire, 15mm in diameter with its turns spaced 2.5mm apart. It is best made by winding about 15 turns, closely spaced, on to a 12.5mm diameter rod. This 15 turn winding is then allowed to expand by its own springiness and slipped off the rod. You will then find it possible to screw the coil into the holes of a small piece of 2.5mm pitch pin board, about 15mm apart. Excess turns are then cut off, leaving the ten turns required, and the ends of the coil soldered to two pins. The single turn tap, shown in Fig. 5, is soldered to a third pin.

Although almost entirely air spaced the resulting coil, visible in Fig. 6, is rigid and mechanically stable. The 10:1 transformation ratio has been effected here geometrically and subsequent measurements with a high impedance voltmeter should verify that it is sufficiently accurate.

As seen in Fig. 6, the circuit is housed in a small diecast box and the power supplies to the photodiode and lamp enter via feed-through capacitors. It is important to use the grounded end of the inductor as the only ground point inside the box. To this single ground are returned the 47pF tuning capacitor, the 0.01µF photodiode decoupling and the 180Ω damping resistor. Grounding to the box itself is then made through the coaxial lead to the output socket. The negative side of the 15V supply is connected at a point near the +15V feed-through.

These grounding precautions are important, especially if you do not have access to a screened environment. Even if well away from the frequency chosen for measurement, interference may induce currents in the earthing system. These currents can give rise to spurious output from the noise generator if you fail to follow the single-point earth rule.

Additional loss required if the circuit is to present a 75Ω output impedance is provided by the 180Ω damping resistor. The actual value of this damping resistor can only be found by measuring the output impedance, which is best done by comparing it with a standard 75Ω termination at the resonant frequency. Of course the Q of the coil must be large enough to ensure that Q/C is greater than 7.5kΩ. As C is 47pF in this design, the Q at 28MHz must exceed 64, which is not at all demanding.

Fixed tuning is used in this design because it greatly simplifies construction and the problems of screening. No great disadvantage follows because the noise generator has a bandwidth greater than 100kHz. When working outside a screened room, it should be possible to find a quiet spot within this bandwidth for making noise factor measurements.

References

in proprietary software on a PC, which provides a menu for operation and demonstration to police forces.

**Combined networks**

Best results have been obtained from a combination of three networks. Two of these are trained to recognise different data representations of a given fingerprint while the third is trained by a combination of the outputs of the first two to give an overall classification of the fingerprint image.

One representation is a digitised and encoded 20 x 20 array of the average directions (measured by angles) of the raised ridges which form a fingerprint. The other representation, called a vorticity map, encodes the curvature of ridges in the image and yields information about the location of features known as cores and deltas. Both are derived from 480 x 480 pixel images.

Each ANN has three interconnected layers of neurons: input (typically 280 neurons), hidden (20) and output (4), using the back error propagation training algorithm. In training, the input layer is presented with a succession of ascii data representations encoded from different fingerprints, while the output layer is presented with the desired output classification data.

Actual outputs resulting from the input data are compared with the desired outputs and the errors are used repeatedly to adjust the internal weighting of the neurons (multiplication) until the error is as close to zero as possible for all the input fingerprints. Convergence is thus achieved, and the network has been trained to recognize any subsequent fingerprint which falls into the desired output pattern classification.

In tests the multiple ANNs have been trained on 118 different examples of each of four main fingerprint pattern types. These four types constitute 91.4% of the total database, the remainder being distributed among four further pattern types. Test results, given in detail by Bowen, show that over 93% of the fingerprints are classified correctly. Probably in practice the residue of images which cannot be processed automatically in this way will have to be classified manually by a fingerprint expert.

**Medical imaging**

Neural networks are also being used to recognise and classify biological patterns in medical imaging. The colloquium revealed two experimental approaches - though both with some way to go before they are likely to get anywhere near clinical practice.

Every year in Britain about 4500 women are diagnosed as having cancer of the cervix and about 2500 of them die of it. But if detected and treated at an early stage the disease can be cured, with a 95% success rate. This is where the NHS national screening programme comes in. Regular cervical smear tests detect any abnormal changes in the size, shape and colouring of cells taken from the surface of the cervix.

But the complex samples have to be inspected through microscopes by human experts. Each smear contains 200,000 cells and takes up to 10 minutes to inspect, so the task is onerous, fatiguing and slow.

Stephen McKenna of Dundee University's Microcentre reported on experiments using neural networks to distinguish between the monochromatic images of individual normal and abnormal cells, each formed by 256 x 256 pixels. For this a set of 80 features is extracted from each image - coincidentally the same number of characteristics in an average fingerprint. The cell image is first converted into a two-dimensional frequency spectrum pattern, using the discrete Fourier transform, to give data compression among other things.

McKenna briefly mentioned work by a colleague, Ian Ricketts, who had used a multi-layer perceptron with a single hidden layer of four neurons and training by back error propagation, as in the Home Office project. This classified 96.3% of 524 cell images correctly. But McKenna's paper was mainly devoted to experiments with a cascade-correlation ANN for the same application.

The idea is to avoid the difficulty with multi-layer networks of finding the best number of hidden layers and neurons. For a specific task, this has to be done experimentally and is not at all straightforward.

Moreover the cascade-correlation ANN is about 20 times faster to train.

Cascade-correlation is what is called a constructive algorithm. You start with a single-layer ANN, train it, then add hidden neurons to it one by one, training as you go, until the network error becomes acceptably small. The added neurons come from a pool of candidates. All these are trained, and the most successful candidates are connected to the output layer while the others are discarded.

The best result achieved with this method, using four hidden neurons, was 95.8% of cervical cells classified correctly. Obviously, where health and life are at stake we need 100% correct classification. So is the ANN automatic inspection technique worth pursuing and can we ethically allow a trade-off between throughput and reliability? When deciding, we should note that expert cyto logical workers can, and have, made mistakes in this field.

**Computerised tomography**

In the second medical imaging application, a combination of two ANNs is used to recognise the presence or absence of a condition called baso-spasm in the brain. This disorder is shown up by blood flow rates in the brain, observed from a series of cross-sectional images obtained by single-photon emission tomography.

Julian Mason, speaking for Warwick University and Walsgrave Hospital, Coventry, explained that the initial images represented 16 transverse "slices" 1cm thick through a patient's brain, constructed by computerised tomography. Arrays of pixels from these were converted into data and applied to two multi-layer perceptrons with back error propagation.

The first ANN was trained on the individual slices and the second on the 16 outputs from the first, thus giving a result for each complete brain. He claimed that correct overall classification on patients was better than 95%.

Again the ANNs were simulated in software on a digital computer. To avoid the great expenditure of time needed to implement a massively parallel network on a serial machine, Mason and colleagues have been considering using commercial logic chips to achieve similar results. But simulated networks using the probabilistic logic node principle 2 have not yet performed satisfactorily.

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