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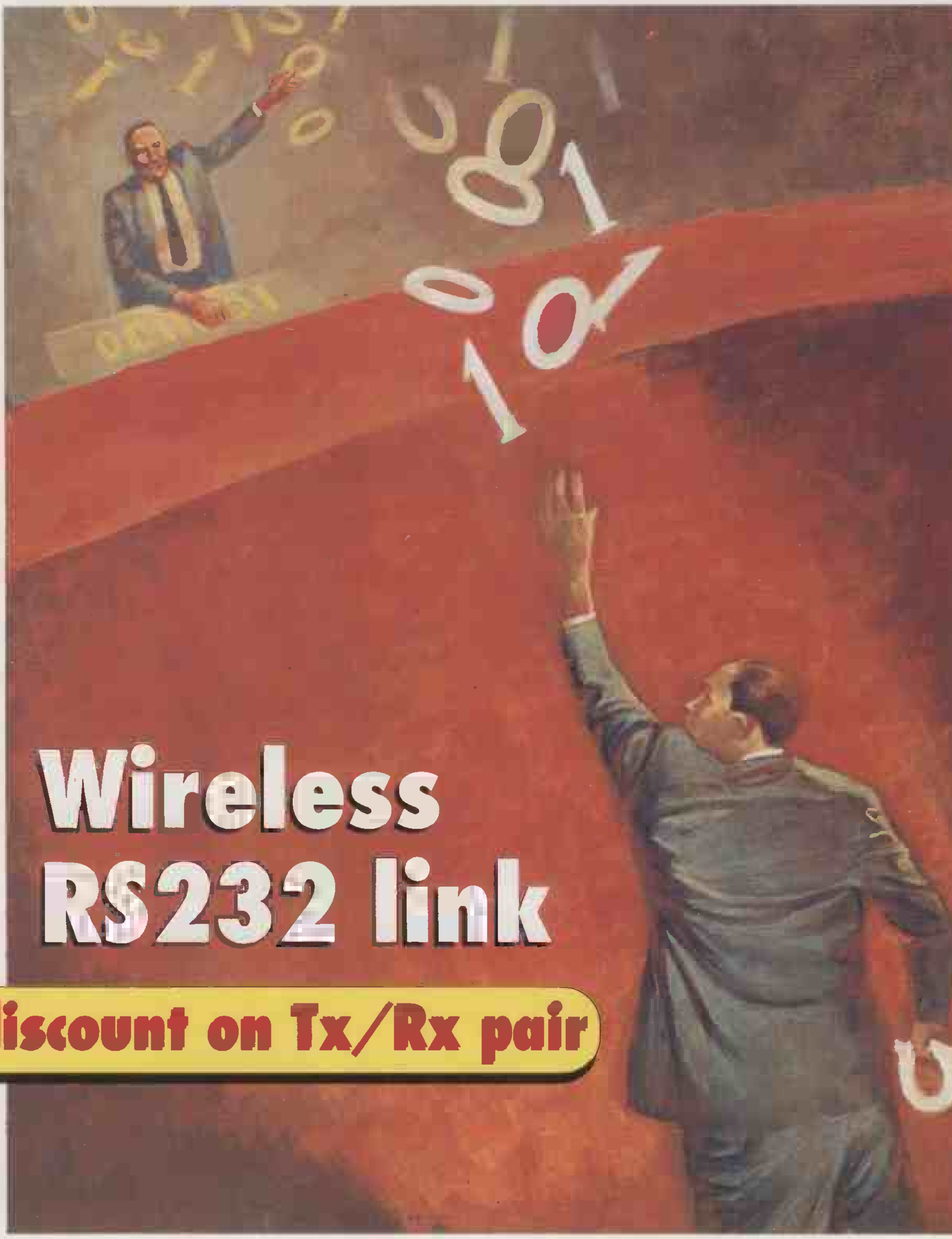

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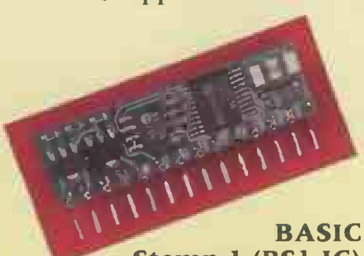

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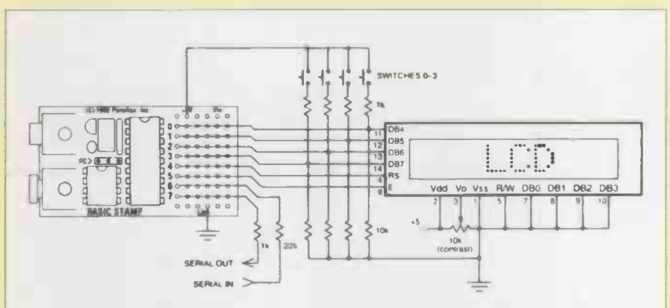

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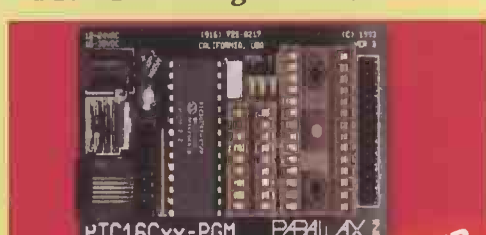

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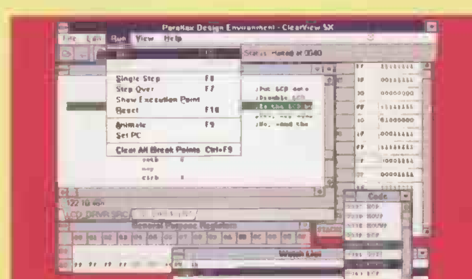

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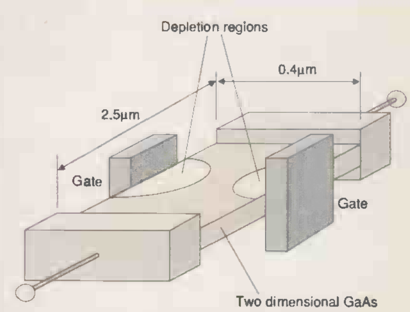
Wireless link modules – 40% discount

Radiometrix is offering a pair of *BiM* Tx/Rx modules for just £60.65. Part of Pei An's design, these devices can be used over distances to 120m at speeds to 40kbit/s - page 454.



The remarkable characteristic of this 2D Mesfet is that it functions with only 200 electrons in its channel, allowing ultra-low-power operation - page 444.

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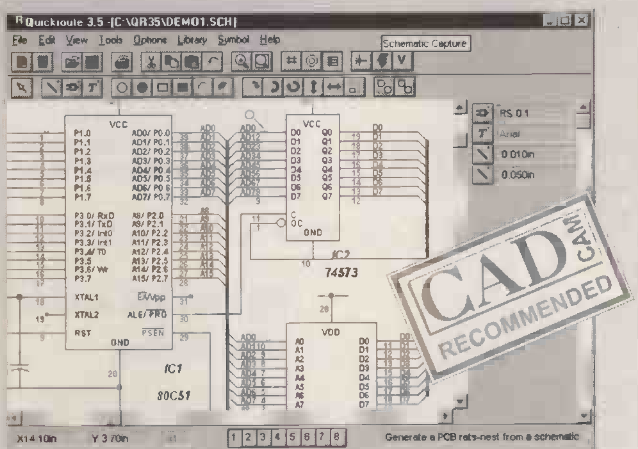

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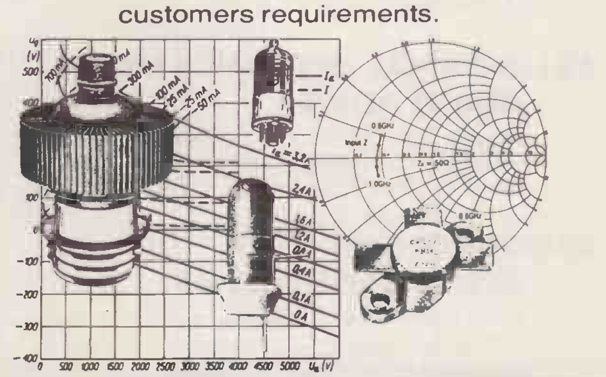

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Thanks – but no thanks

Over many years, I have watched in horror as electronics companies launched products which seemed to have been designed without any thought for the paying customer. Even as they hit the market, we just knew they were going to fail.

This represents a tricky dilemma journalists covering electronics. Should we write off the product as a flop, and thereby help to make it one? Or should we try to give it a helping hand, thereby putting consumers at risk of buying something that will later become obsolete?

In the case of Sir Clive Sinclair's C5 trike, it was an easy call. No matter that the battery went flat as quickly as anyone who has flattened a car battery with the starter could have predicted. Had Sir Clive ever actually tried taking one out on a busy road, and seen how it felt to be next to the wheels of a lorry?

Last year ICL and Fujitsu joined forces to launch the Indiana range of PCTVs. Soon after Olivetti followed suit with Envision. These three companies had one thing in common; no experience in consumer electronics. Even so it is hard to imagine how their designers could have made such a basic mistake.

Although the idea of using one tv screen for both a pc and tv is superficially seductive, there is an obvious and fatal flaw. Television screens are intended to display relatively low resolution tv transmissions. They look fine from across the room. Move close to a tv set you see interlace jitter; horizontal lines flicker vertically as the fields change. On 50Hz PAL sets, there is the added problem of wide area flicker on bright white images. The colour shadow-mask pitch is coarse, to match the tv scanning raster. So PC text and graphics look coarse too.

A tv screen makes a rotten pc display. That is why, after the era of Sinclair Spectrums and Amstrads, the pc industry moved away from tv standards, to higher refresh rates, and started to sell pcs with dedicated monitors.

Did anyone inside ICL, Fujitsu and Olivetti ever sit down in front of their own PCTVs and actually try some serious word processing, database building or spread sheet design? Apparently not.

Like blood from a stone I have now squeezed the admission that production of Indiana and Envision stopped last winter, and neither ICL/Fujitsu or Olivetti has any firm plans for the future.

Philips developed Laservision, the 12in optical video disc, in the seventies. Rival electronics companies all round the world very quickly saw the elegance of laser read-out and gave up their research on alternative systems. Never mind that Laservision was launched later than promised, and was thus faced with competition from the vcr. The technology spawned CD, CD-ROM and recordable disc.

Stubbornly, RCA pressed ahead with CED Selectavision, a 12in grooved capacitance disc that needed a caddy. It was launched in the US and UK, but plain as pikestaff never had a chance. Hardly a disc played without skipping and the player had to incorporate a 'nudge control' to knock the stylus when it stuck in the groove. RCA's blinkered vision cost the company so much in hard cash that its name and trade infrastructure were bought by Thomson of France.

Commodore once had a healthy share of the computer and games market. Seeing Philips preparing for the launch of CD-interactive, Commodore dreamed up the idea of CDTV – an Amiga-based interactive CD that was incompatible with the Philips format. Commodore hoped that by rushing to the market ahead of Philips, CDTV would become the *de facto* standard.

One selling point was that the CDTV player was also a CD player. So how could Commodore have made the basic mistake of using a computer CD-ROM drive that played discs only when loaded into a caddy? Commodore's answer was that CD data discs need protection from finger marks.

With caddies costing around £5 a time, it was impractical to give one away with each CDTV disc. Audio CDs come in jewel boxes, anyway. So Commodore gave away one free caddy with each player and the owner had to load each disc in the caddy before playing it.

Instead of taking a CD out of its jewel box and loading it into a CD player tray, the owner had to take the CD out of the jewel box, and load it in the caddy before loading the caddy in the player. There was no less handling of the disc, just extra inconvenience.

The caddy issue raises its ugly head again later this year, but from the opposite direction. Toshiba, Thomson and Time-Warner are promising to launch high density DVD movie players, with Philips, Sony and others following next year, in less of a rush. By early May there was still no final agreement on vital standards issues, such as copy protection to prevent people dubbing high quality movies from disc to tape, and regional control, to stop movies released in the USA playing on European players.

But there is one issue on which the DVD Alliance is solid. Having learned from Commodore's mistake on CDTV the hardware and software companies have pledged that the DVD system will not need a caddy. Discs will be packaged like ordinary CDs and loaded direct into a tray in the player.

How strange then that some prototype DVD players still use caddies. Although the more modern prototypes use caddy-less tray loading, it pays to watch any DVD display and see how the demonstrator handles the discs – with extreme care, at the extreme edges.

No-one grabs a DVD disc with sticky fingers. But unfortunately this is exactly how the public treats CDs. They will treat DVDs that way too. Will the error correction cope? We are assured it will, even though the capacity of the new disc is so much greater, thanks to pits that are so much smaller.

If the DVD Alliance launch their system without first giving players and discs to sticky fingered next door neighbours, they could pay the same price paid by Sir Clive, RCA, ICL, Fujitsu, Olivetti and Commodore. That price is horrendously expensive failure thanks to the public's reluctance to pay money for neatly packaged inconvenience. ■

Barry Fox

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EMC all over again?

Wireless LAN technology connecting handheld pcs – including one from SAIC the UK ruggedised computer supplier – is being tested for electromagnetic compatibility in Russia's Mir space station. A 2.45GHz spread spectrum wireless LAN from US company Proxim was taken up to the space station on the space shuttle Endeavor in March. According to Yuri Gawdiak, a NASA computer engineer: "Today's astronauts are surrounded by miles and miles of cable. Wireless networks eliminate their need." One important aspect of the emc tests will be the system's susceptibility to the impact of cosmic particles on processors and memory devices.

Last year's panic over the introduction of CE marking for the EMC Directive is set to be repeated when the net technical harmonisation standard rears its head. If industry thought emc compliance caused problems, then enter the Low Voltage Directive, or LVD.

According to industry experts, many electronics engineers and manufacturing companies have little understanding of the LVD.

Andrew Perkins, instrument sales manager for Schaffner EMC, involved in conducting seminars said: "People's knowledge of the LVD is akin to that of the EMC Directive this time last year. Less than 5% of people attending the seminars are doing the tests correctly."

The lack of understanding is also resulting in few companies conforming to the Directive.

As of January 1, 1997, the LVD attains the same status as the EMC Directive, with manufacturers being required to CE mark for LVD conformity.

This means that someone will have to sign a declaration of conformity and will be held accountable in law.

Safety divisional manager at TRL EMC is Simon Barrowcliff. "Small and medium sized companies are exhibiting good engineering practice in most cases", he said. "They are designing for safety but they are not conforming to the LVD."

While the DTI has provided information on the LVD, its spread over several years has resulted in it lacking the profile of the successful emc campaign. This, however, is likely to change in the coming eight months.

Richard Ball, *Electronics Weekly*

What is the Low Voltage Directive?

- The LVD is the standard specifying design and testing of equipment connected to the mains. The 'Low' refers to voltages below 1kVac and 1.5kVdc. It differs from the EMC Directive in several significant respects:
- The LVD dates from 1973 and is one of the first technical harmonisation standards. This has given companies ample time to prepare for LVD-day. Unlike the EMC Directive, there is no excuse for ignorance and little or no leniency will be allowed.
- Harmonised European standards for the LVD are much more complex. Longer design and testing time will be necessary to ensure total compliance by 1997. One route to compliance is via approval schemes such as the BABT scheme for telecoms and the BEAB for consumer and white goods. These specify third party type testing and formal quality systems such as ISO9001. Smaller companies with less funds and manpower may find these schemes prohibitive in cost and time.
- More information: DTI booklet, Tel: 01179 444 888.

EMC amnesty for UK manufacturers

British electronics manufacturers have been given an 'unofficial' emc breathing space by the government.

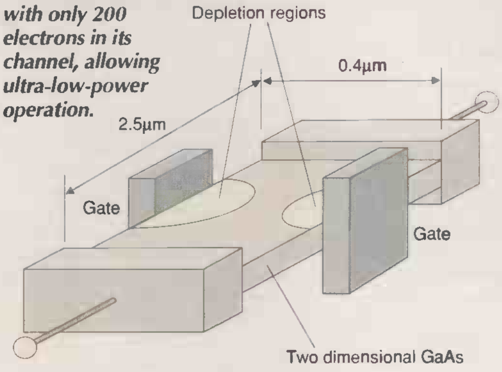
The DTI has told local trading standards officers, who have been officially policing the EMC Directive since January, to take a lenient approach to enforcement at least for this year.

"There has been guidance to local authorities to allow a period of grace," said David Roderick, director of the safety committee for the Institute of Trading Standards.

In a move, which seems to be out of step with the rest of Europe, the DTI appears to be responding "sympathetically" to those suppliers waiting to have their products qualified in test houses. "There is concern about the test houses not being able to cope, so where people have made attempts to get things done, we will look upon it sympathetically," said Roderick. No one in the UK has yet been prosecuted under the EMC Directive, and Roderick believes any prosecutions are unlikely in the near future.

Ultra-low power 2D mesfet nearer production

The remarkable characteristic of this 2D Mesfet is that it functions with only 200 electrons in its channel, allowing ultra-low-power operation.



University of Virginia's research group that recently demonstrated an ultra-low power two dimensional mesfet has moved a step closer towards a production version.

The remarkable characteristic of the original device is that it operates properly with only 200 electrons in its channel. Conventional fet structures are swamped by second order effects at such low currents.

The advance is in the construction of the device. The developmental fet was made using a AlGaAs/InGaAs/GaAs heterostructure, built up layer by layer on the substrate and patterned using an electron beam. Bill Peatman, a member of the team said: "This technique is not at all suited to mass production."

The newest version is constructed using ion implanted bulk n-doped GaAs – a conventional technique and material.

Peatman said: "We made two transistors with the same geometry, one with the original construction and one by ion implanting bulk GaAs. The two behave very similarly, and were closely predicted by our theoretical models."

The channel of the 2D mesfet is a 0.4µm wide strip connecting the drain and source. The strip is only a few nanometres thick, hence the 2D label. Gates on either side of the channel control the width of the conduction region within.

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Plastic lights

Cambridge Display Technology, CDT, is to give the first public demonstration of its light emitting polymer display in San Diego.

The forum is the Society for Information Display's annual conference and the device is a 60 column by 16 row photo-emissive dot matrix.

The display is said to combine characteristics of leds and lcds. Mark Gostick, a spokesman for CDT, said: "The technology has the emissivity of leds, with the patternability of lcds. Light is emitted wherever activated electrodes cross one another."

Although the demonstration is a dot matrix display, the first commercial use is likely to be as a backlight. Gostick said: "The life to 50% brightness is currently 3000 hours. This is perceived to be a bit short for a display, but easily long enough for a backlight."

Light emitting polymer backlights offer similar advantages to electro luminescent materials. They are extremely thin, with the same emissivity and a similar lifetime.

The stated advantage of light emitting polymers is that they only require several volts, eliminating the inverter normally associated with electroluminescent lights. Gostick said: "The lack of an inverter makes a light emitting polymer backlight cost less to produce than the equivalent electroluminescent panel."

Most of the development displays made by CDT so far have been green and on glass substrates, but other types have been made. Gostick said: "We have made red and blue versions, the blue ones are the most difficult to produce. We have also made some flexible displays on plastic film, but the lifetime is not as good as the glass ones yet."

Steve Bush, *Electronics Weekly*

Satellite tracker handles big waves

Receiving satellite transmissions at sea presents difficulties, with the signal being lost when the boat turns, pitches and rolls. This can be overcome by gyroscopically directed dishes; but the comparatively low power of satellites has meant that these have had to be large.

The launch of three high power digital satellites by GM Hughes Electronics has enabled KVH Industries of Rhode Island to produce a compact system capable of operating up to 200 miles off the US coast.

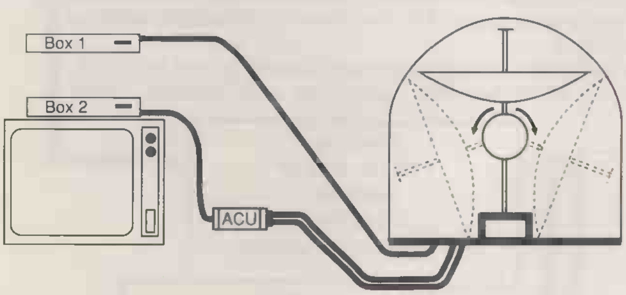
The *TracVision* actively stabilised antenna has an 18in carbon fibre dish guided by a robotic arm to maintain tracking accuracy to within 1°. It uses a digital, Earth-referenced compass and attitude sensors to hold directional information over long periods of time, with digital gyroscopes to provide instant directional information.

Measurements are relayed to the cpu, where software calculates the rate of the movements and translates them to stable, land-based coordinates. These are then converted to commands in the motor control unit to guide the robotic arm.

Two motors power the arm and antenna in the opposite direction to the movement of the vessel. It is capable of locating the target satellite with or without GPS information. The elevation range is ±110° from vertical, azimuth range is 360° continuous, and the tracking rate is 18°/s at horizontal.

Received video signals are passed to a set-top receiver box. A patented robotics gimbal joint system prevents cables from wrapping around the antenna pedestal and causing transmission breaks.

A smaller *Tracphone* version has also been produced. It has an 11.5in dish for satellite phone and fax communications. With this version, internal sensors measure the heading, pitch and roll of the vessel relative to the satellite. These are then transmitted to a microprocessor that directs the motors controlling the arm and dish.



This marine satellite tracker can move at 18°/s. It has a 110° elevation range and can rotate through 360°.

IN BRIEF

Power fet resistance lowered to 260mΩ

Motorola has announced its next generation of power fet technology – hdtmos-2 – which gives a 30% reduction in R_{DSon} compared with the original hdtmos process.

Significant structural changes have bought the resistance of a 2mm×2mm chip down from 800mΩ to 260mΩ. Sample devices are expected in the second quarter of this year.

Chip prices softening

Softening chip prices could be hit further as 14 new fabs come on stream before the end of June, and at least 16 more are due to start up in the second half of the year. The total for the year could be as many as 40 new fabs.

These are in addition to 60 fabs which, according to US analysts, came on-stream last year: 19 in America, 12 in Japan, 11 in Europe and 18 in Asia.

FCC considers Internet radio band

The US Federal Communications Commission is considering setting aside a band of radio frequencies for high speed Internet access over short distances. The FCC says it may set aside two bands of frequencies in the 5.15-to-5.35GHz and 5.725-to-5.875GHz bands for use by wireless computer devices that would send and receive data over a 0.25 mile range at rates as high as 25Mbits/s.

"Low-power radio technology can serve as a low-cost, high-bandwidth on-ramp to the information superhighway," said FCC Commissioner Susan Ness. The FCC has been petitioned by Apple Computer and the Wireless Information Networks Forum to set aside the frequencies.

Apple and other supporters say that these radio frequencies could be used for campus style local area networks. These would operate over a university or corporate campus linking computer users, and would be a cheap alternative to cellular phone or PCS networks.

Apple is also proposing a related technology that would allow high speed wireless data communications over a 9.6 mile range at 1.5Mbits/s. Using wireless technology could prove popular within corporate offices and save on the considerable expense of rewiring offices for high speed networks. ■

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Hart Audio Kits and factory assembled units use the unique combination of circuit designs by the renowned John Linsley Hood, the very best audiophile components, and our own engineering expertise, to give you unbeatable performance and unbelievable value for money. We have always led the field for easy home construction to professional standards, even in the sixties we were using easily assembled printed circuits when Heathkit in America were still using tagboards!. Many years of experience and innovation, going back to the early Dinsdale and Bailey classics gives us incomparable design background in the needs of the home constructor. This simply means that building a Hart kit is a real pleasure, resulting in a piece of equipment that not only saves you money but you will be proud to own.
Why not buy the reprints and construction manual for the kit you are interested in to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.

K1100 AUDIO DESIGN 80 WATT POWER AMPLIFIER.

This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hifi system. This kit is your way to get ůK performance at bargain basement prices. Unique design features such as fully FET stabilised power supplies give this amplifier World Class performance with startling clarity and transparency of sound, allied to the famous HART quality of components and ease of construction.
Useful options are a stereo LED power meter and a versatile passive front end giving switched inputs, with ALPS precision Blue Velvet low-noise volume and balance controls. Construction is very simple and enjoyable with all the difficult work done for you, even the wiring is preterminated, ready for instant use!. All versions are available with Standard components or specially selected Super Audiophile components at £29.60 extra per channel, plus ů2.40 if you want to include Gold Plated speaker terminals.

K1100B Complete STANDARD Amplifier Kit. £395.21
A1100B Factory Assembled. £499.21
K1100SC Complete SLAVE Amplifier Kit. £333.62
A1100SC Factory Assembled. £422.62
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A1100M Factory Assembled. £329.20
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K1100CM Construction Manual with full parts lists £5.50

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This unit provides a high quality headphone output for 'stand alone' use or to supplement those many power amplifiers that do not have a headphone facility. Easily installed with special link-through feature the unit draws its power from our new Andante Ultra High Quality linear toroidal supply. Housed in the neat, black finished, Hart minibox it features the wide frequency response, low-distortion and 'musicality' that one associates with designs from the renowned John Linsley Hood. Pre-terminated interconnecting leads and PCB mounted sockets prevent supply polarity reversal and on-board diagnostics provide visual indication of supply line integrity. Volume and balance controls are Alps "Blue Velvet" components. Very easily built, even by beginners, since all components fit directly on the single printed circuit board. The kit has very detailed instructions, and even comes with a complementary roll of Hart audiograde silver solder. It can also be supplied factory assembled and tested. Selling for less than the total cost of all the components, if they were bought separately, this unit represents incredible value for money and makes an attractive and harmonious addition to any hifi system.

K2100 Complete Kit. £109.50
K2100SA Series Audiophile version with selected audiophile components. £112.46
A2100SA Series Audiophile version, factory Assembled. . . . £149.46
K3565 "Andante" Power Supply Kit to suit "Chiara". £85.42
A3565 Power Supply, Factory Assembled. £128.42
CM2100 Construction Manual. £2.50
SPECIAL OFFER. Both units together, Kit Form. £184.92
Factory Assembled and Tested. £267.88

"Andante" SERIES 20VA AUDIOPHILE POWER SUPPLIES

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Utilising linear technology throughout for smoothness and musicality makes it the perfect partner for any module requiring fully stabilised ±15v supplies.
Two versions are available. K3550 has 2 ±15v supplies and a single 15v for relays etc, and can be used with our K1400 preamp and our K1450 RIAA pickup preamp, as well as other useful modules soon to be introduced. The K3565 is identical in appearance but only has the ±15v lighter current supply for use with the K1450 RIAA pickup pre amplifier or "Chiara" headphone amplifier.

K3550 Full Supply with all outputs. £93.75
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Now you can throw out those noisy ill-matched carbon pots and replace with the famous Hart exclusive ALPS 'Blue Velvet' range components only used selectively in the very top flight of World class amplifiers. The improvement in track accuracy and matching really is incredible giving better tonal balance between channels and rock solid image stability. Motorised versions have 5v DC motor.

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NEW! Another Classic by John Linsley Hood. "AUDIO ELECTRONICS" Following the enormous ongoing success of his "Art of Linear Electronics" the latest offering is the all-new edition of "Audio Electronics", now entirely re-written by the master himself. Underlying audio techniques and equipment is a world of electronics that determines the quality of sound. For anyone involved in designing, adapting or using digital or analogue audio equipment understanding electronics leads to far greater control over the reproduced sound. The subjects covered include tape recording, tuners, power output stages, digital audio, test instruments and loudspeaker crossover systems. John's lifetime of experience and personal innovation in this field allow him to apply his gift of being so familiar with his subject that he can write clearly about it and make it both interesting and comprehensible to the reader. Containing 240 pages and over 250 line illustrations this new book represents great value for money at only £18.99*

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The definitive linear electronics and audio book by John Linsley Hood. This 300+ page book will give you an unparalleled insight into the workings of all types of audio circuits. Learn how to read circuit diagrams and understand amplifiers and how they are designed to give the best sound. The virtues and vices of passive and active components are examined and there are separate sections covering power supplies and the sources of noise and hum. As one would expect from this writer the history and derivation of audio amplifier circuitry have an entire chapter, as does test and measurement equipment. Copiously illustrated this book is incredible value for the amount of information it contains on the much neglected field of linear, as opposed to digital, electronics. Indeed it must be destined to become the standard reference for all who work, or are interested in, this field. Latest reprinted edition with extended index. 1994 344 Pages. 247 x 190. 1Kg. 0-7506-0868-4. . . . . £16.95*

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HP signal generators type 626 – 628 – frequency 10GHz – 21GHz.
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CIRCLE NO. 111 ON REPLY CARD

Jonathan Campbell

Energy technology is truly green

Plants can exploit virtually every photon they absorb to create a working electron that is efficiently taken up into chemical processes. Our own efforts in making electricity from the Sun using solid state devices are a lot less efficient. But a team from University of California and Princeton University looks to have taken a step towards developing a technology that uses a mechanism much closer to that used in nature.

The technology is based on materials given the name 'chemophylls' because of the way they mimic the chlorophyll process. A prototype chemophyll is a stable preparation that binds a layer of electron-donor substance (papd) to a layer of an electron acceptor substance (pv). The donor papd can be grown as true film, without crystalline structure, while the acceptor pd forms extremely small crystals that can be neatly arrayed in layers one molecule deep.

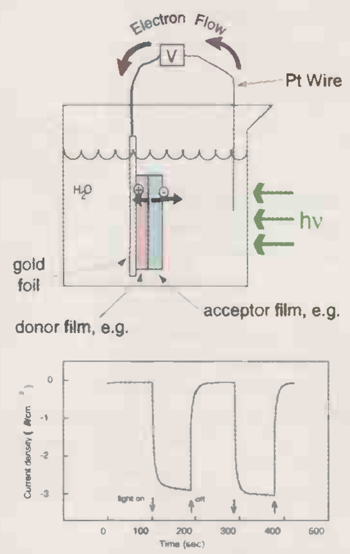
Both papd and pd consist of an active core sandwiched between structures called phosphonates. Atoms of zirconium bind to the phosphonates, tying the assembled 'sandwiches' to one another. The structure resembles a stack of papd and pd sandwiches piled on an ultra-thin sheet of gold foil. Sandwiches with papd 'filling' alternate with sandwiches with pd filling, and zirconium atoms hold them together.

When illuminated with light, electrons move from the papd to the pd, creating an electrical potential. By providing an appropriate receptor material to accept the electrons on the other side of the surface, a continuing, one-way flow is set up.

University of Southern California chemist Mark E Thompson, leader of the scientific group responsible for the prototype's creation, explains the possible application of the chemophyll: "While this material would be inefficient at powering a device, like a radio or a hair dryer, that runs on electric current, it could be an extremely effective power source for light-induced chemical reactions, such as breaking down water into oxygen and hydrogen or making natural gas out of the carbon in carbon dioxide to create clean-burning fuels."

Three characteristics make it particularly interesting. It is produced in extraordinarily uniform layers and can deliver its energy evenly throughout an entire surface of arbitrarily large size. It can also be applied as a coating to an irregular surface.

Like chlorophyll – and unlike silicon cells – its photovoltaic action is a wet process, working in an electrolyte solution conducive to chemical reactions. It might even float on top of a liquid that would form the raw material for the chemical reaction.



Chemophyll's photovoltaic action is a wet process, working in an electrolyte solution, and could even float on top of a liquid that would form the raw material for the chemical reaction itself. The graph shows cathode photocurrents produced by an Au.papd/pv electrode with an electron acceptor in solution.

Finally, although the conversion efficiency of the material so far prepared is low, the team is confident that materials of similar structure with much higher efficiencies can be made.

More information from Mark Thompson, Associate Professor, Department of Chemistry, University of Southern California, Los Angeles, CA 90089-0744, USA. Tel: (213) 740-6402 Fax: (213) 740-0930 email: mthompso@chem1.usc.edu

Micromachines get a little intelligence

Several research teams have recently made breakthroughs in the manufacture of micromachines. Now researchers at Sandia National Laboratories, Albuquerque have taken the next step by giving their micromachines built in intelligence.

Unlike previous machines, an intelligent micromachine can signal for more power, communicate that it is operating too fast or slow, or even perform actions on an automated basis. But using standard fabrication techniques, machines consisting of tiny motors with integrated circuit 'brains' on individual silicon chips – are now being mass produced by Sandia researchers.

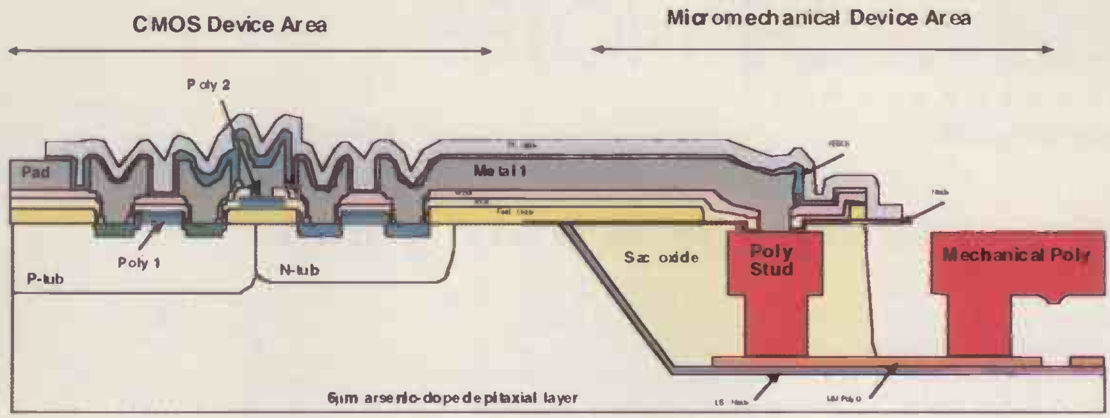
Compact design, made possible by sinking the motors in tiny etched trenches, enables the fabrication of entire electromechanical systems on a chip.

In the past, the difficulty with joining a microcircuit to a micromachine on a silicon chip has been that aluminum circuit interconnectors, if formed first, melt when the micromachines are heat-treated. But if the micromachines are fabricated first, their elevation above the chip surface creates bumps that distort the delicate process of etching accurate microcircuits.

In the Sandia process tiny trenches are etched in silicon chips and the machines are fabricated within these depressions. The machines, heat-treated, are then submerged in a tiny hardening sea of silicon dioxide. The hardened silicon dioxide re-creates a level chip surface upon which circuitry is fabricated by

A dust mite puts the new generation of micromachines in perspective.

Micromachine and control circuitry fabricated on a chip.



photolithography. Removal of the silicon dioxide at the end of the process frees the microengines. Working systems are manufactured with a 78% success rate – a reasonably high measure of production yield.

The micromachines are approximately 1mm square embedded in chip trenches 6µm deep, producing a single level structure suitable for accelerometers and other sensors. Three-level structures have been fabricated to a depth of 18µm.

Circuits fabricated only microns from a machine also eliminate ghost signals – parasitic currents – created by excess electrical capacitance in long connecting wires.

"Without this interference, by applying a mechanical load you can measure the capacitance change in the drive gear teeth as they move in and out," says Sandia engineer Ernest Garcia. "Then you know how fast the machine is moving. The sequence allows you to understand velocity."

Analog Devices, the largest producer of automated airbag sensors in the US, says it is already having preliminary talks with Sandia to use its technology in prototype devices.

More information from Ernest Garcia, Sandia National Laboratories, Albuquerque, New Mexico, 87185-0167

Optical switch polarises arguments

A light-activated optical switch under development at the Georgia Institute of Technology could be the basis for a new type of rewritable three-dimensional data storage system. By making use of a small number of 'trigger molecules' to induce a phase transition in liquid crystal materials, the system would write, read and erase information using different forms of polarised and unpolarised light.

Such an optical storage system could offer significant advantages over conventional computer floppy disks, magnetic tape and compact disks, which use two-dimensional media to store data. The optical switch materials could also be used in spatial light modulators, and in active coatings for optical fibres.

The idea is that the liquid crystal could be written to, with circularly-polarised light, read from, with linearly-polarised light, and erased, with unpolarised light.

Operation of the new optical switch is based on chiral molecules that Gary Schuster, professor of chemistry at Georgia Tech, and co-workers are using to trigger changes in the liquid crystal. Chiral molecules exist in right-handed and left-handed forms. Each form is affected differently by circularly-polarised light – which also exists in right-handed and left-handed versions.

Georgia Tech researchers have been making microscope studies of liquid crystals suspended in glycerol, which helps to provide information about key properties.

When right-handed trigger molecules are struck by left-handed light they may be converted preferentially to left-handed molecules. If the chiral molecules are dissolved in a liquid crystal material, this structural change can be used to prompt a phase transition in the crystal, altering the optical properties of the liquid crystal material.

Multiple phase transition 'switches' could therefore be used together to store digital information.

Returning the storage material to its original state would make the system truly rewritable — and of significant potential value as a computer data storage media, for example.

Schuster believes the system is an improvement over earlier optical switches not only because it is rewritable, but also because a small number of photons can trigger the phase transition. This makes the liquid crystals amplifiers for the photonic signal.

Before the switches become useful for optical data storage, they must be converted from two-dimensional layers to a true three-dimensional system, perhaps written by three-dimensional holograms.

Development of practical optical switches has long been frustrated by the lack of suitable materials. Optical materials studied earlier used irreversible photochemical changes to store information. That meant data could be written to them only once, limiting their practical value for computer information storage.

Though the Georgia Tech system shows promise, Schuster emphasises that much work remains to be done before it could reach practical application.

"From a scientific point of view, looking off into the future, this is what we hope to do with these materials," he said. "Our grandchildren might see the first computers based on this system."

More information from Gary Schuster at Georgia Institute of Technology Atlanta, Georgia 30332-0828

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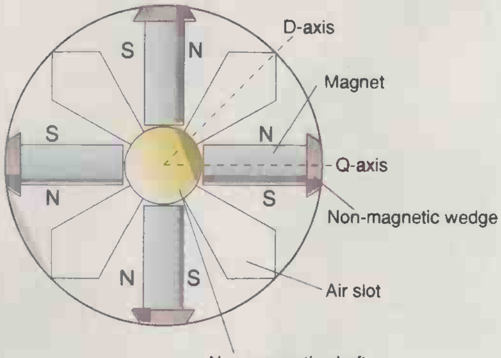
Researchers pack more power into electric motor

Two researchers in the Department of Electrical and Electronic Engineering, University of Hong Kong, claim to have invented a new design of permanent magnet motor that promises much higher power densities and efficiencies than other similar units. The permanent magnet synchronous motor drive has been developed for electric vehicle applications, with the greater power density resulting in savings in energy and space.

Rotor configuration with air slots that is enabling greater motor power densities to be achieved.



Improvements in the motor's performance have been bought about by developing a special rotor geometry and using new neodymium-iron-boron magnets that have only recently become available.

In the past, efforts to boost the power density of pmsms have relied on increasing the flux density in the air gap – resulting in a smaller effective gap and leading to a strong armature reaction which limits the force density of the motor.

But the Hong Kong researchers say they have reduced this armature reaction considerably by making air slots along the D-axis within the motor ('An advanced permanent magnet motor drive system for battery-powered electric vehicles', CC Chan and KT Chau, *IEEE Transactions on Vehicular Technology*, Vol 45, No 1).

According to Chan and Chau the improvement is possible because in the new design, the air slot at each pole centre has to be bridged by the armature field while the flux path for the excitation field experiences only an insignificant change. Power density of the experimental motor is 2009kW/m^3.

So far a prototype of the 3.2kW battery powered drive system has been designed and built for an experimental vehicle. Specifications for the vehicle are a top speed of 30km/h, an acceleration of 0-20km/h in 8s and a payload rating of 200kg, able to be carried up a 15° gradient.

In principle, the proposed pmsm could be scaled up to fit the needs of a regular on-road electric vehicle with a 50kW motor. But the researchers warn that any economic advantages would be diminished because of the need for bigger quantities of the relatively expensive magnetic material.

More information from the authors at University of Hong Kong, Pokfulam Road, Hong Kong.

How to take in twice as much information?

In the stimulus-overload world of the multimedia '90s, with the amount of data squeezed on to a computer screen nearing saturation point, we plainly need some new thinking on how to cope with this out-pouring of information. Now a team of Japanese researchers have come up with an answer – simply add another screen!

According to the researchers from Hitachi's Central Research Laboratory, conventional display systems are simply not capable of coping with the abundance of information being presented.

"Multi display systems, rather than single-display systems, may be more suitable for taking advantage of a multimedia environment," is the conclusion.

Fortunately, that doesn't mean we have to worry about our brains – and necks – seizing up as we twitch from screen to screen (to screen) surrounding our desks. Well not yet anyway. Because the solution proposed is an altogether friendlier foldable flat-screen display that looks as much like a book as a computer peripheral.

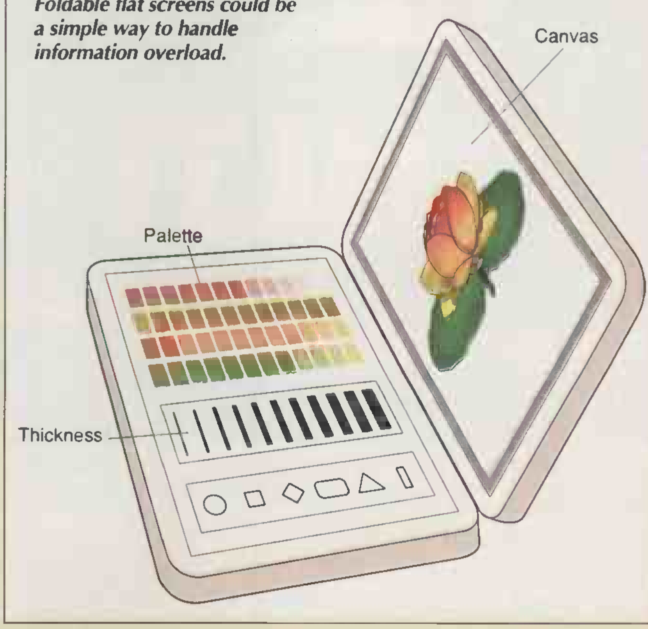
The prototype foldable display system built by the team ('Foldable-display systems as a standard platform for multimedia use', Y Kaneko *et al*, 'IEEE Transactions on Consumer Electronics', Vol 42, No 1.) is based on connecting two or more active matrix lcds mechanically and electrically. The resulting system can be opened up and laid on a table.

Possible applications suggested by the researchers are by using one screen as the palette space with details on brushes etc, and the other as the canvas. In more general terms, the system could be useful wherever information needs to be manipulated and data, tools and a work space are all needed. Another application being tested is in an electronic translator. Two people sit with the display between them, looking at equivalent text, inverted towards them, in their respective languages.

Pointing to a phrase by touching the screen by one person causes the equivalent phrase to be displayed on the other screen in the foreign language.

There could be economic advantages as well, as two 250mm active-matrix lcds are much cheaper to produce than a single display with the same area, about 355mm diagonally.

Foldable flat screens could be a simple way to handle information overload.



If the Hitachi prototype makes it into production, it looks as though we may have a route to turbo-charging the output of information from our computers – but what about the input? We already use a keyboard and mouse together, and can even talk to some machines. But don't you feel a little frustrated that your feet have nothing to do?

More information from Yoshiyuki Kaneko at the Central Research Laboratory, Hitachi Ltd, Kokubunji, Tokyo 185, Japan.

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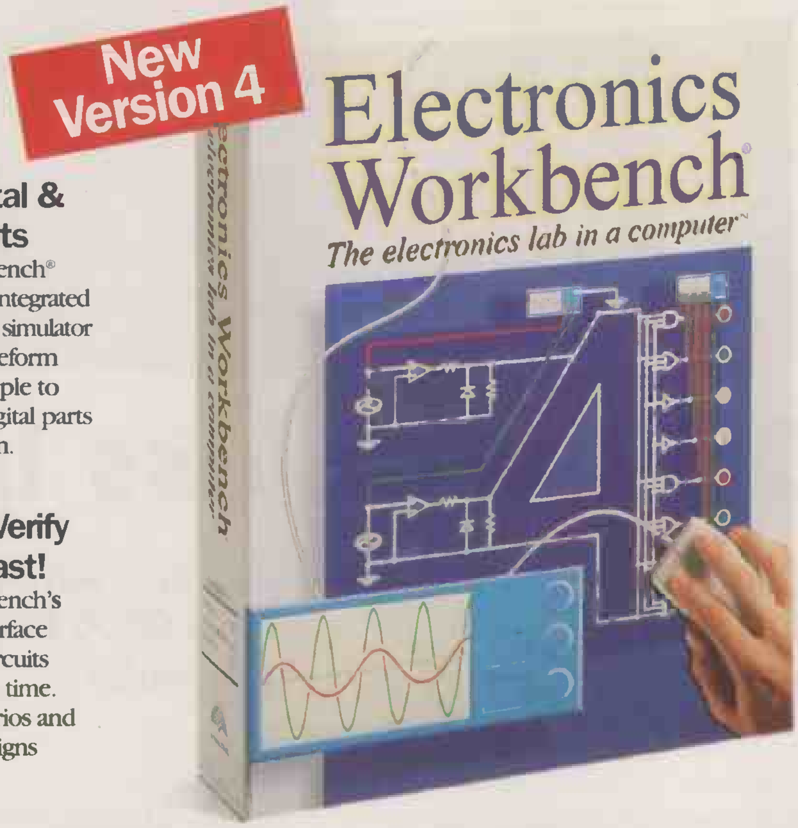

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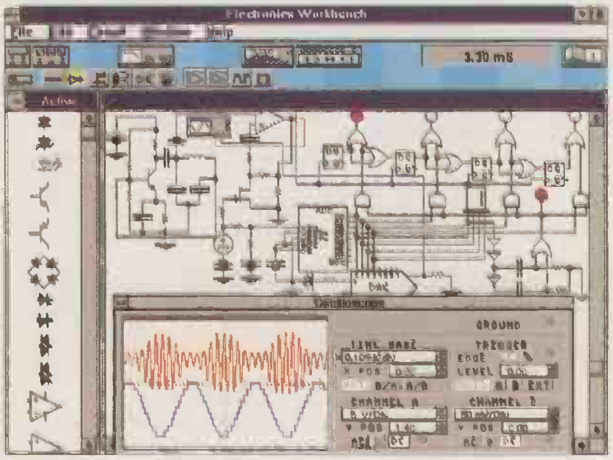

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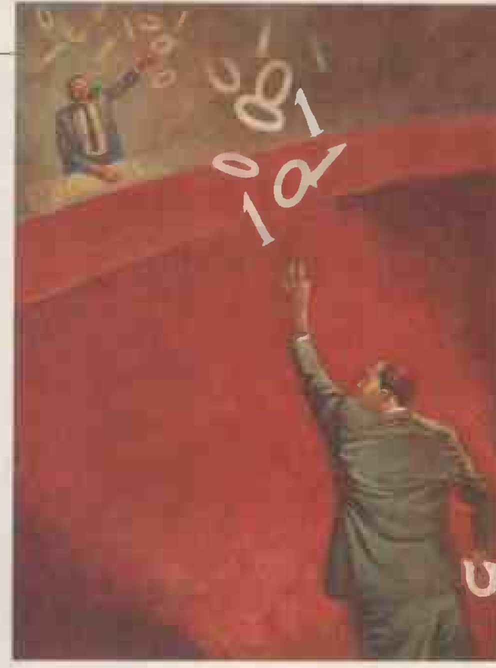


Computer
RS232 wireless link

Covering distances of up to 120m, Pei An's wireless RS232 link hardware operates at up to 9600 baud via type-approved transmitter/receiver modules.

This article introduces a radio communication system which allows two or more computers to communicate with each other over a wireless link via their RS232 interfaces. Reliable communication can be achieved over a distance of 30 metres in buildings or 120 metres on open ground.

The radio link uses Radiometrix low power 418MHz uhf fm data transceiver modules which are type-approved to the Radio-communication Authority Specification MPT1340 in the U.K. This avoids the need to submit the final product for further approval.

By implementing suitable software, this system can form a local computer network. It can also be used for remote sensing or remote control applications.

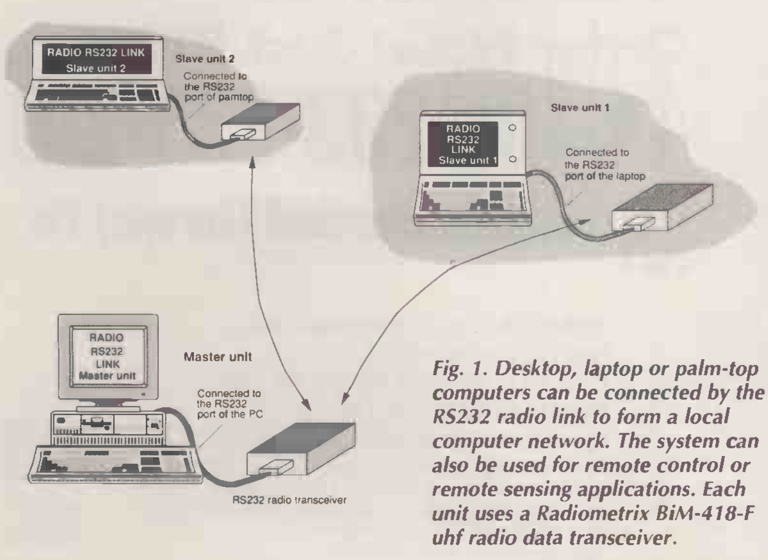


Fig. 1. Desktop, laptop or palm-top computers can be connected by the RS232 radio link to form a local computer network. The system can also be used for remote control or remote sensing applications. Each unit uses a Radiometrix BiM-418-F uhf radio data transceiver.

How the system works

The system consists of a number of identical radio transmitter/receiver units, each connected to the RS232 interface of the various computers, **Fig. 1**. Each unit can be configured as a transmitter or a receiver. When it is configured as a transmitter, serial data from the RS232 interface is fm modulated by a uhf radio-frequency carrier signal and is transmitted to the surroundings. If it is configured as a receiver, radio signals picked up by the antenna are demodulated. Demodulated data – the serial data put into the transmitter – is fed into the RS232 interface.

A system may include one master unit and several slave units. By using appropriate software, half-duplex data transmission can be achieved between the master unit and the other units, Fig. 1.

RS232 interfacing

The RS232 is an industrial standard bi-directional asynchronous serial data communication interface for data communication between two devices. With computers, it is frequently used for connecting peripherals such as printers, modems and mice.

A pc's parallel port comprises eight data lines and information is conveyed one byte at a time. Unlike the parallel i/o port, the serial COM port has only one line for data transfer in either direction. Each eight-bit byte is transmitted or received serially, one bit at a time.

With asynchronous data transmission, the transmitted signal contains both data and synchronisation information. This synchronisation information enables the receiver to reassemble, or 'frame', the serially transmitted words correctly back into parallel form.

The format of the transmitted serial data includes a start bit, 7 or 8 serial data bits, a parity check bit and 1 or 1.5 stop bits. **Figure 2** shows a typical serial data format. The receiver device, which runs at the same clock frequency as the transmitter, detects the start bit and receives the data bits. It checks the parity bit and upon receiving the stop bit it terminates the data receiving cycle and waits for the next transmission. The rate at which data bits are sent is measured by baud rate.

In practice, the asynchronous communication is facilitated by a family of industrial standard computer peripheral ICs known as uarts, or universal asynchronous receiver and transmitters. Most computers use a *8250* or *16450* uart. These devices operate at ttl voltage levels but RS232 operates at higher, bipolar voltages. For this reason, ttl-to-RS232 and RS232-to-ttl converters are needed.

The pc's RS232 interface

A standard RS232 interface is a 25-pin interface, which is housed in a 25-pin D-type male connector. A 9-pin version is also used on pcs. **Figure 3** gives the pin layout and functions of the RS232 connectors viewed from the back of the computer. The functions of the pins are briefly described as follows:

Prot – protective ground line. This pin connects the metal screening of the cable to the chassis of the equipment.
GND – Ground line provides a common voltage reference for all signals.
TD – Transmitting data output. Serial data is transmitted on this line.
RD – Receiving data input receives serial data.
RTS – Request to send is a handshake output indicating that a transmitting device is ready to send data. If handshake is not required, it can be used as an output.
CTS – Clear to send is a handshake input from which a receiving device is informed to receive data. If handshaking is not used, it could be used as an input.
DTR – Data terminal ready is a handshake output and indicates that a transmitting device is ready. If handshaking is not used, it can be used as an output.
DSR – Data set ready is a handshake input from which a receiving device is informed that the data set is ready. If handshaking is not used, it could be used as an input.

An pc-compatible computer can have up to four RS232 interfaces. They are labelled COM1 to COM4. Each COM port is associated with a uart chip inside the computer. Operations of the COM port are controlled by internal registers of the uart. For register functions, see **Table 1**.

The i/o addresses of each internal register is calculated by adding the offset to the base address of a COM port. Table 1 shows the i/o address for COM port 1 which has a base address of $3F8_{16}$.

Some registers are used for the wireless link described here. Register 00_{16} (data buffer register) stores the received data and the data to be transmitted. Register 04_{16}, the modem control register, controls the status of RTS and DTR of the port. When handshaking is not required, the two lines can be used as outputs. Register 06_{16}, the modem status register, stores the status of CTS and DSR, which, when handshaking is not used, can be used as two inputs.

Base i/o addresses for COM1 to COM4 are summarised in **Table 2**.

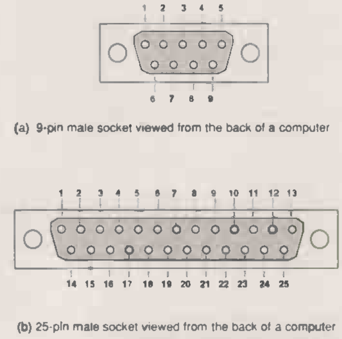
Table 1. Functions of the pc uart's internal registers.

Offset	Address	Function	Description
00_{16}	$3F8_{16}$	Receiver buffer register Transmitter buffer register	Store received data Store data to be transmitted (useful register)
01_{16}	$3F9_{16}$	Interrupt enable register	Set the mode of interrupt request
02_{16}	$3FA_{16}$	Interrupt identification register	Check mode of interrupt request
03_{16}	$3FB_{16}$	Data format register	Set the format of serial data transmission (useful register)
04_{16}	$3FC_{16}$	Modem control register	Set modem controls (RTS, DTR, etc) (useful register)
05_{16}	$3FD_{16}$	Serialisation status register	Contains information on status of receiver and transmitter
06_{16}	$3FE_{16}$	Modem status register	Contains the current status of DCD, RI, DSR and CTS. (useful register)
07_{16}	$3FF_{16}$	Scratch-pad register	Acts as one-byte memory

Table 2. Base i/o addresses for the pc's COM ports.

Interface	Base address	Addresses for internal registers
COM1	$3F8_{16}$	$3F8\text{-}3FF_{16}$
COM2	$2F8_{16}$	$2F8\text{-}2FF_{16}$
COM3	$3E8_{16}$	$3E8\text{-}3EF_{16}$
COM4	$2E8_{16}$	$2E8\text{-}2EF_{16}$

Fig. 2. Format of serial data generated by uarts. This example has eight data bits (data bits 0 to 7), one parity check bit and one stop bit. The start bit is for synchronising the receiving devices.



Standard pin functions of the RS232 connectors

25 PIN	9 PIN	NAME	DIRECTION (FOR PCS)	DESCRIPTION
1		Prot	-	Protective ground
2	3	TD	OUTPUT	Transmit data
3	2	RD	INPUT	Receive data
4	7	RTS	OUTPUT	Request to send
5	8	CTS	INPUT	Clear to send
6	6	DSR	INPUT	Data set ready
7	5	GND	-	Signal ground (common)
8	1	DCD	INPUT	Data carrier detect
20	4	DTR	OUTPUT	Data terminal ready
22	9	RI	INPUT	Ring indicator
23		DSRD	I/O	Data signal rate detector

Fig. 3. Pin layout and functions of the pc's RS232 connector.

Connecting devices using RS232

Two types of RS232 link are shown in **Figure 4**. The arrows show the direction of data flow. Figure 4a) is known as a null modem. Some lines of the two RS232 interfaces are used as handshakes between the two devices.

Figure 4b) shows a connection using only three lines. One line is for transmitting data and the other for receiving data. The connection is arranged so that the transmitting line of the first device, TD, is connected to the receiving line of the second device, RD.

Software control

Before a COM port can be used, it must be configured. This configuration includes setting of the following: the bit rate, length of data bits, number of stop bits and the parity check bit. Two computers communicating with each other must have the same configuration. There are three methods of carrying out the configuration.

● The first method is to use DOS command 'MODE' under DOS prompt. The syntax of the command is:

```
MODE COMm: baud=b, parity=p, data=d,
  stop=s, retry=r
```

or

```
MODE COMm: b, p, d, s, r
```

Functions of specifiers in the command can be found in any DOS handbook[1]. For example 'MODE COM1: 96,n,8,1' configures COM port 1 to have a baud rate of 9600, no parity check, 8 bit data length and 1 bit stop bit. This command can be included in the autoexec.bat file.

● The second method is to use a basic-input-output-system, or BIOS, interrupt. This allows the interface to be configured from within the user's program. It requires that register AH is loaded with 0, DX is loaded with a number 0 to 3 representing COM1 to COM4 to be configured, and AL is loaded with an 8-bit initialisation code. The bit function of this code is shown in **Table 3**.

The following Turbo Pascal program shows how to achieve the same function as the DOS command 'MODE COM1: 96,n,8,1'. The initialisation code is **11100011B**.

```
Procedure initialise;
{COM1:  9600, no parity check, 8 bit data
  and 1 stop bit}
var register:registers;
begin
with register do begin
ah:=0; {load interrupt function number}
al:=128+64+32+0+0+0+2+1; {load
  initialisation code, 11100011B}
dx:=0; {COM1 is to be initialised}
intr($14, register); {Call the BIOS
  interrupt}
end;
end;
```

● The third method configures the COM port by writing data directly into the data format register, at offset=03_{16}, of the uart. This method is slightly involved and outside the scope of this article. Details can be found however in other pc hardware books[2].

Table 3. BIOS initialisation bit functions.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Define bit rate bits			Define parity check		Stop Bit	Data length	
111= 9600	011= 600		00= No parity		0= 1	10= 7 bit	
110= 4800	010= 300		10= No parity		1= 2	11= 8 bit	
101= 2400	001= 150		01= Odd				
100= 1200	000= 110		11= Even				

Fig. 4. RS232 pin connections between pcs and external devices.

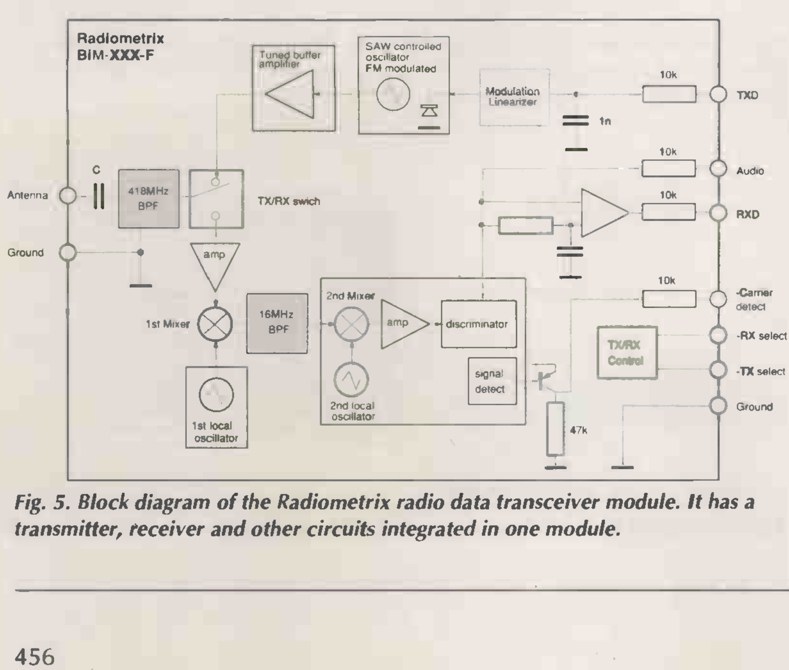


Fig. 5. Block diagram of the Radiometrix radio data transceiver module. It has a transmitter, receiver and other circuits integrated in one module.

Sending and reading serial data

There are several ways to read and send serial data via the RS232 interface. The following method is the most flexible one as far as pc interfacing is concerned. The method is known as direct port access.

To send data out of the COM1 interface, you can write data directly to the data buffer register, $3F8_{16}$ – the base address of COM1. The following instructions can be used:

```
OUT 3F8h, X in BASIC, and
PORT[$3F8]:=X in Turbo Pascal
```

X is the data in decimal. To read data from the COM1 port, we can read data from the data buffer register, $3F8_{16}$ and the following commands can be used:

```
Y=INP[3F8h]in BASIC, and
Y:=PORT[$3F8] in Turbo Pascal
```

where Y is the input byte in decimal.

Reading and writing data via handshake lines

To output data from the RTS and DTR lines, you should write to the modem control register at offset 04_{16}. Data bits DB0 and DB1 correspond to RTS and DTR. The following Turbo Pascal command makes the RTS and DTR lines of port COM1 go low. Note that both lines are inverted by ttl-RS232 transceivers inside the pc.

```
PORT[$3F8+4]:=2+1
```

To read data from DSR and CTS lines, you should read the modem status register at offset 06_{16}. Data bits DB5 and DB4 correspond to the DSR and CTS lines of the port. Again, these two lines are inverted by ttl-RS232 transceivers.

COM port base addresses

The base addresses for different COM ports have been shown earlier. A convenient way to find the addresses automatically is to use software commands.

When the computer is switched on or reset, the BIOS checks all possible RS232 addresses. If it finds an installed one, it writes the addresses of the port, in a two-byte word, to specific memory locations. For COM1, the locations are $0000{:}0400_{16}$ and $000{:}0401_{16}$. By peeking these locations, the base address can be obtained. Memory locations for COM1 to COM4 are listed below.

Port	Memory address
COM1	$0000{:}0400$ - $0000{:}0401_{16}$
COM2	$0000{:}0402$ - $0000{:}0403_{16}$
COM3	$0000{:}0404$ - $0000{:}0405_{16}$
COM4	$0000{:}0406$ - $0000{:}0407_{16}$

Another useful one-byte memory location is $000{:}4011_{16}$. It stores the total number of installed COM ports. The information is contained in bits 3, 2 and 1 of the byte. Data bits 7 to 4 and 0 are used for other purposes.

DB3	DB2	DB1	Number of RS232 ports installed
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4

The following example in Turbo Pascal 6 first detects the number of RS232 interfaces installed on the pc and assigns the number to a variable, namely 'Number_of_COM'. It then reads from the memory locations holding the base address of COM1 and assigns the address to the variable 'COM1_address'.

```
Procedure detect_COM1;
var
COM1_address,number_of_COM:integer;
begin
number_of_COM:=mem[$0000:$0411]; {read
  number of parallel ports}
number_of_COM:=(number_of_COM and
  (8+4+2)) shr 1; {DB3, DB2 and DB1
  extracted from the byte}
COM1_address:=memw[$0000:$0400]; {Memory
  read procedure}
writeln('Number of COM installed :
  ',number_of_COM:2);
writeln('Addresses for COM1 :',
  COM1_address:3);
end;
```

Data transceiver module details

This wireless link uses wireless data transceiver modules supplied by Radiometrix. I recommend that you obtain a full descriptions of the modules before you try to implement them[3].

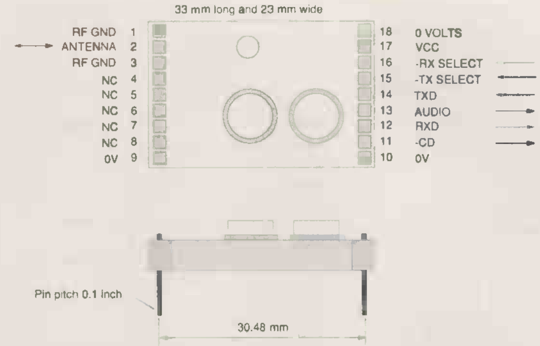
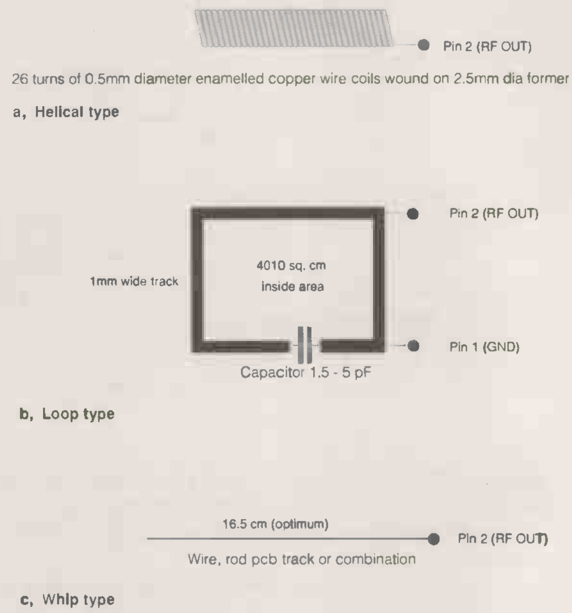


Fig. 6. Mechanical dimension and pin functions of the BiM transceiver.



Antenna performance chart

	Helical	Loop	Whip
Ultimate performance	√√	√	√√√
Ease of set-up	√√	√	√√√
Size	√√√	√√	√
Immunity to proximity de-tuning	√√	√√√	√

Fig. 7. Comparison of antenna options for BiM transmitter/receiver modules.

The modules are available in two types, namely *BiM-418-F* and *BiM-433-F*. The first operates at 418MHz and is type-approved to MPT1340 of the Radio Communication Authority in the UK. The latter is for European use in the 433.92MHz band.

Both modules provide a low-cost solution for a bi-directional half duplex data transmission at speeds up to 40kbit/s over a distance of 30 metres inside buildings and 120 metres on open ground. The block diagram of the module, its mechanical dimensions and pin functions are shown in **Figs 5&6**.

The module consists of a uhf fm transmitter and a matching superheterodyne receiver. For the transmitter, digital data is fed into a modulation lineariser via an *R/C* low-pass filter. This filter restricts the bandwidth of the modulation signal.

Output of the lineariser drives a varicap diode, the changing capacitance of which modifies the frequency of a uhf

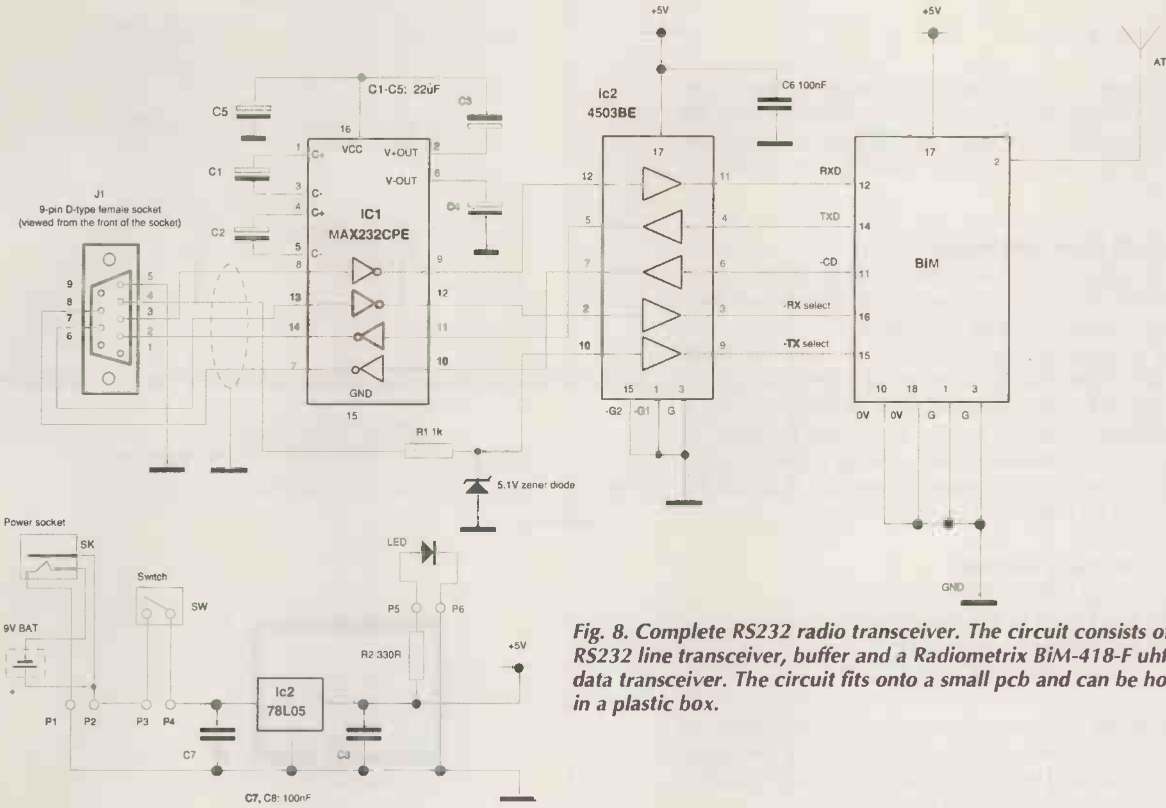


Fig. 8. Complete RS232 radio transceiver. The circuit consists of an RS232 line transceiver, buffer and a Radiometrix BiM-418-F uhf radio data transceiver. The circuit fits onto a small pcb and can be housed in a plastic box.

oscillator. The centre frequency of the oscillator is derived from a surface acoustic wave (SAW) resonator. The modulated uhf signal is amplified by a tuned buffer amplifier and fed to a Tx/Rx switch.

After passing through the switch, the signal is emitted to the surroundings via the antenna. For the receiver, the uhf signal picked up by the antenna is switched to the receiver section. It is amplified and fed into the first mixer. As a result, a modulated signal at an intermediate frequency of 16MHz is produced. This IF passes through a 16MHz band pass filter and enters the second mixer. After that the signal is amplified and fed into the discriminator, where an audio signal is produced. The signal then passes through a data slicer, converting the analogue signal to digital form.

The antenna is used by both the transmitter and by the receiver. Switching is controlled by the Tx/Rx analogue switch and the operation of it is controlled by a transmit/receive selection circuit.

Pin-functions of the Tx/Rx module

Pin functions of the module are briefly described as follows. Pins 9, 10 and 18 are the ground pins, i.e. 0V, which are connected to the negative rail of the power supply. Pin 17 is the positive supply pin, V_{cc}.

A dc supply voltage between 4.5V to 5.5V should be connected. Applying a voltage above 5.5V or reversing the polarity of the power supply will cause permanent damage to the module. When the module is in transmit and receive modes, current assumption is about 12mA. In the stand-by mode, current reduces to about 1μA.

Pin 14 is the transmit data input pin (TXD). It can be driven directly by cmos logic running on the same supply voltage as the module. Analogue signals generated by modems or dtmf encoders can also be fed into this pin.

Pin 12 is the output of the received data. It can be connected directly to cmos logic. Pin 13 is the output of the analogue signals. It can be used with modems or dtmf decoders. Carrier detect is output on pin 11, –CD. When the module is in receive mode, a low state on –CD indicates a signal above the detection threshold is being received. This output can only drive one COM ports logic input.

Pins 15 (–TX) and 16 (–RX) are used for selecting operation modes of the modules. They could select one of the four modes listed below.

Pin 15 (–TX)	Pin 16 (–RX)	Modes
1	1	Stand-by
1	0	Receive
0	1	Transmit
0	0	Self test loop

Pins 1 and 3 are the rf ground. They are internally connected to Pins 9, 10 and 18 and should be connected to the ground plane of user's pcb board against which the antenna radiates. Pin 2 connects to the antenna.

Antenna

Three types of integral antenna are recommended and approved for use with these modules. The configuration of the antenna and selection chart are given in Fig. 7. The present system utilises a helical type antenna.

Table 4. BiM and RS232 port pin relationships.

RS232 interface pin	Pin of the BiM module
RD, receive data, pin 2	TXD, transmit data
CTS, clear to send, pin 8, used as an input	–CD, carrier detect
TD, transmit data, pin 3	RXD, receive data
RTS, request to send, pin 7, used as an output	–RX, receive select
DTR, data terminal ready,pin 4, used as an output	–TX, transmit select
GND, signal ground, pin 5	GND, ground

Type approval

The *BiM-418-F* is type-proved to the RA MPT1340 for license exempt use within the UK for telemetry, telecommand and in-building security – but only provided that the following requirements are met[4].

- The transmitting antenna must be one of the three variants given above.
- The transmitter module must be directly and permanently connected to the transmitting antenna without the use of an external feed. Increasing the rf power level by any means is not permitted.
- The module must not be modified nor used outside its specification limits.
- The module may only be used to send digital data. Speech or music is not permitted.
- Equipment in which the module is used must carry an inspection mark located on the outside of the equipment and clearly visible, the minimum dimensions of the inspection mark must be 10 by 15mm and the letter and figure height must be not less than 2mm. The wording must read: "MPT 1340 W.T. LICENSE EXEMPT".
- The trimmer control on the module must be inaccessible to the end user. This control is factory set and must never be adjusted.

Failure to meet the above conditions invalidates the modules' type approval. Further information on MPT1340 specification issued by the RA (DTI) may be obtained from the RA's library service on +44-(0)171-211-0211.

Requirement for digital data transfer

The data path through a pair of BiMs is ac coupled and there are several requirements for successful data transfer. Pulse width time – the time between two consecutive transitions in the serial code – must be between 25μs and 2ms.

Receiver BiMs require at least 3ms of 10101010 bit-sequence preamble to be transmitted before the actual data is transferred. The receiver is optimised for data waveforms with 50:50 mark-to-space averaged over any 4ms period. It will work reliably for sustained asymmetry up to 30/70 either way. But this will result in pulse-width distortion and decreased noise tolerance.

RS232 radio link hardware

The system consists of a number of identical units which are connected to computers via the RS232 interface. The transmission rate of the system is 9600 baud.

Figure 8 is the complete circuit diagram. It consists of three blocks, namely, the RS232/COM driver unit, the *BiM-418-F* module and the power supply system. The first unit is built around the *TC232* RS232 driver, IC_1. This IC requires a single 5V power supply and converts the right voltage levels for the RS232 standard and COM port logic.

One of the RS232 output lines, DTR, is converted to the COM-port logic level using a simple voltage clamp circuit using a 5.1V zener diode. All the signal lines between the *TC232* and the *BiM-418-F* are buffered by the *4503BE*, IC_2. The pins of the BiM and RS232 are connected as shown in **Table 4**.

The *78L05* 5V voltage regulator requires between 8 and 15V dc input. Suggested component layout and assembly of the unit is shown in **Fig. 9**.

Software requirements

RS232 serial data can be transmitted at 4.8 to 38.3kbit/s between a pair of BiMs. In order to send RS232 serial data through the BiMs, the data needs to be packetised to meet the Tx/Rx module requirements. The packetised data includes the following parts:

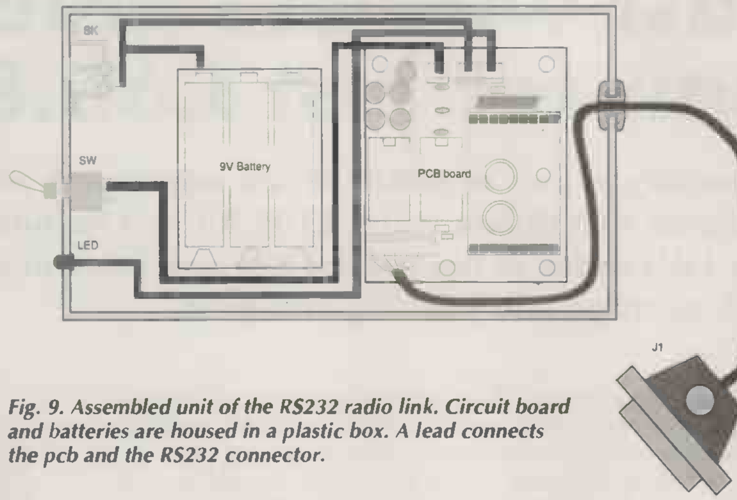


Fig. 9. Assembled unit of the RS232 radio link. Circuit board and batteries are housed in a plastic box. A lead connects the pcb and the RS232 connector.

- 3ms of preamble data of 55_{16} or AA_{16} to allow the receiver BiM to settle.
- one or two bytes of FF_{16}.
- one byte of 01_{16} to show the start of data.
- data bytes and
- check bits.

In practice, the format of the packetised data may vary according to the users' needs.

There are three methods of improving the mark-space ratio of the serial data to be transferred.

Method 1. Each byte is divided in half. The first half is the bit to be sent and the second half is its complement. Each byte has a guaranteed mark-to-space ratio of 50:50.

Method 2. Amongst the 256 possible eight-bit codes, 70 codes contain four zeros and four ones, which have a 50:50 mark-to-space ratio. Examples of these are, 17_{16}, $1B_{16}$, 27_{16}, and $E8_{16}$. They can be transferred between two RS232 ports using a data format of one start bit and one stop bit with no parity check bit. The actual data to be sent will be translated using these codes and then transferred. This also allows byte checking on receipt as all received codes must contain exactly four ones and four zeros.

Method 3. Each byte is sent twice. The first one is the true data and the other is its complement. This will again give a 50:50 mark-to-space ratio.

Control software in Turbo Pascal has been written to demonstrate data communication between two computers via the system.

Technical support

Designers' kits and assembled units together with demonstration software are available from the author. Please direct your enquiry to Dr Pei An, 58 Lamport Court, Lamport Close, Manchester M1 7EG. Tel: Ans/Fax: +44-(0)161-272-8279. If you would like to obtain more information on the BiMs, contact Radiometrix Ltd, Tel: +44-(0)181-810 8647, Fax: +44-(0)181-810-8648. ■

References

1. Microsoft DOS 6.0 manual.
2. Hans-Peter Messmer, The indispensable PC hardware book, Addison-Wesley publishing company, ISBN 0-201-62424-9.
3. Radiometrix Ltd. Low power UHF data transceiver module.
4. Radiocommunication Agency (RA), MPT1340, obtained from RA library service, Tel 0171-211 0211.

Fast wireless data transceiver pair for just £60.80

Normally, a pair of BiM418F uhf transceiver modules, as used in Pei An's wireless RS232 link, costs £105.84. But Radiometrix is offering one pair only per *EW* reader at the special discount price of just £60.80 – fully inclusive of VAT, postage and packing and data.

Operating at 418MHz, these modules are capable of half-duplex data communication at speeds to 40kbit/s over distances of 30m inside buildings or 120m over open ground.

The modules integrate a low-power uhf transmitter and matching dual-superheterodyne receiver together with data recovery and Tx/Rx changeover switching. Requiring a single 4.5 to 5.5V supply, the modules interface directly to 5V c-mos logic.

High data rates and fast Tx/Rx changeover of less than 1ms make the BiM transceiver ideal for high integrity one to one links/multi-node packet switch networks. Rapid Rx power up – also less than 1m – allows effective duty cycle power saving of the receiver for battery powered applications. For example, current flow is on average 15μA for 1ms on and 1s off cycling.

Typical applications of the transceivers are:
- Medium speed computer networks
- Laptop to pc to printer links
- High integrity wirefree fire/security alarms
- Building environment control/monitoring
- Vehicle alarm systems
- Remote meter reading
- Authorization/access control

UK Version – BiM-418-F
Euro Version – BiM-433-F

Operating at 418MHz, these modules are capable of half-duplex data communication at speeds to 40kbit/s over distances of 30m inside buildings or 120m over open ground.

Features of the BiM transceivers
- Miniature pcb mounting module
- Licence exempt operation in UK on 418MHz, MPT 1340 (BiM-418-F)
- ETS 300-220 tested for European use on 433.92MHz (BiM-433-F)
- SAW controlled fm transmission at –6dBm erp.
- Double conversion Superhet receiver
- –107dBm receive sensitivity
- Single 4.5 to 5.5V supply <15mA – Tx or Rx
- Half duplex data at upto 40kbit/s
- Reliable 30 metre in-building range
- Direct interface to 5V c-mos logic
- Fast 1ms power up enable for duty cycle power saving
- On board data slicer, supply switches and antenna change over

Order form
To receive your BiM418F transceiver pair with full data sheet, fill in this coupon and send it to Radiometrix Ltd at Clausen House, Perivale Industrial Park, Horsenden Lane South, Greenford, Middlesex UB6 7QE, together with a cheque or postal order. Please note that this offer closes on Friday 30 August. For further information, write to or call Radiometrix on 0181 810 8647, or fax on 810 8648.

Please send one pair, BiM4128F ❑ or one pair, BiM433F (433.92MHz) ❑

to
Name

Company (if any)

Address

Post Code
Day time telephone
For which I enclose a cheque/PO for £60.80 payable to Radiometrix.

Exactly a century ago, Marconi filed a patent representing the beginning of a new era in communication. Tom Ivall looks at that patent and events surrounding it.

The first radio patent

When Guglielmo Marconi applied for a patent on his wireless telegraphy apparatus exactly a hundred years ago he was in effect announcing the start of an era. Electromagnetic radiation outside the visible spectrum could now be utilised as an aid to human communication. It was the beginning of a new technology and commercial enterprise.

British Patent No. 12039, 'Improvements in transmitting electrical impulses and signals and in apparatus therefor', application date 2 June 1896, was the world's first radio patent. Queen Victoria was still on the throne.

It wasn't a discovery and Marconi was more inventor than scientist. Physicists and others had already been experimenting with this form of radiated energy for a decade or more, though without fully understanding what they were dealing with. They certainly had no practical applications in mind. Branly in France, Hughes and Lodge in England, Popov in Russia and Thomson in America, among others, had all detected apparent radiation from electrical discharges – some natural, some artificially generated – but it was not explored much further. The electron was as yet unknown.

Certainly Maxwell had defined the conditions for the propagation of electromagnetic waves – calculating their speed and inferring that light might be one form of them – as early as the years 1861-1865. His Royal Society paper 'A dynamical theory of the electro-magnetic field' was to become a scientific classic. But the experimental physicists of the time were either unaware of it or sceptical of what they considered a dubious concept.

Helmholtz in Germany, however, eventually understood the importance of this mathematically-based theory. It was under him, in Berlin, that Heinrich Hertz was then working as an assistant professor. Helmholtz realised that the theory needed experimental verification and invited Hertz to attempt it.

After several years this challenge resulted in the famous series of experiments of 1886 at Karlsruhe technical high school – described in Annalen der Physik of 1887 and 1888.

Marconi – 1874-1937 – was a resourceful and determined experimenter. Combining manual skills with a huge capacity for sustained hard work, he became a highly successful developer and entrepreneur.

Hertz's experiments

Hertz generated electromagnetic radiation with an induction coil, a spark gap and what we now call a dipole aerial. He detected it with a tuneable loop resonator containing another, very small, spark gap. He demonstrated that the radiation had the characteristics of waves and, like light, could be reflected, refracted, diffracted, polarised and made to produce interference patterns. His method was to set up standing waves with a sheet metal reflector and locate their nodes with the loop resonator. Thus he validated Maxwell's theory.

It was Hertz, incidentally, who pointed out the irrelevance of Maxwell's original notion, derived from analogies, that there had to be some kind of physical medium which the electric and magnetic forces acted upon – an aether. The essential relationships, he said, were in the equations themselves.

Hertz's laboratory experiments were recognised everywhere. Branly, Lodge and Popov among others immediately repeated them and gave demonstrations to scientific and non-technical audiences. Yet despite the fact that telegraphy existed and some of its pioneers like Morse and Preece had long been seeking a wire-less version, few seemed to realise that the Hertzian waves, as they became known, were offering them a potent new means of electrical signalling. The exceptions were Crookes, who predicted this possibility in 1892, and Lodge, who demonstrated in 1894 that it could be done.

Marconi's interest piqued

One of the scientists who followed up Hertz's experiments, however, was Righi at Bologna University. Marconi, then a teenager living near Bologna, had attended his lectures and studied his writings on e-m radiation. This was the start of Marconi's interest in Hertzian

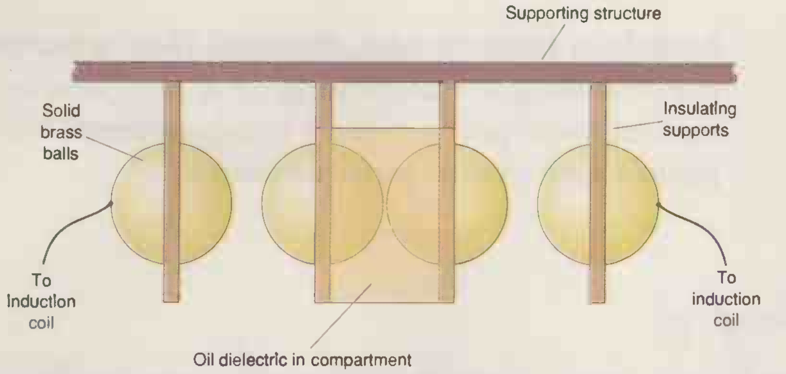


Fig. 1. Hertzian radiator formed by array of spark gaps. This is mounted at the focus of a cylindrical parabolic reflector (not shown).

waves. But it was later, in 1894, after reading more about Hertz's work, that he became fired with the idea of using these waves for communication. Then began the famous series of radio signalling experiments at his home in 1895.

These experiments at Bologna used apparatus broadly similar to that of the physicists who had followed Hertz's work. The transmitter was a keyed induction coil producing high-voltage pulses, a spark gap and a short Hertzian, or half-wave, dipole aerial. The receiver was little more than a dipole aerial with a non-rectifying detector in the form of a Branly type of coherer – though the term coherer was actually coined by Lodge.

Initially, the ranges achieved were very short – up to about 100 metres. But then Marconi had the idea, suggested by Popov's experiments in detecting distant thunderstorms, of replacing the Hertzian dipole in both transmitter and receiver with an elevated electrode, or antenna, on one side and an earthed metal plate on the other.

Marconi's important idea

These modifications gave a tremendous increase in range – eventually, with an 8m high antenna, to about 2.4km. Thus Marconi had devised what is now called the quarter-wave monopole, or Marconi aerial, in which a reflection or image of the quarter-wave element corresponds to the lower element of a vertical half-wave dipole. Some consider this to be his most important contribution to radio technology.

Marconi's transmitter, like those of Hertz and the other scientists, was a device for generating and radiating electrical oscillations. Henry had already observed such oscillations in a discharging capacitor (Leyden jar). The Hertzian oscillator was essentially an *LCR* series resonance circuit containing a spark gap which acted as a switch. The *L*, *C* and *R* were those distributed in the wiring, spark gap and radiating conductors. This circuit, of course, had a natural frequency.

A high-voltage pulse from the induction-coil secondary winding, initiated by interrupting the primary circuit, starts to build up charges on the metal spheres of the spark gap. The electric field within the gap increases correspondingly until the breakdown potential is reached, at which an electrical discharge takes place through the ionised air in the gap. This conduction reduces the gap resistance to a low value and closes the *LCR* circuit, which goes into natural oscillation.

Oscillation continues for as long as the spark discharge is maintained and hence the 'switch' is closed. But resistance quickly dissipates the power, reducing the oscillation amplitude and resulting in a damped oscillatory waveform. With the gap potential falling, the discharge eventually stops; thus the spark gap switch opens the *LCR* circuit and the oscillation ceases. When the next high-voltage pulse arrives from the induction coil the process is repeated.

But the *R* in this circuit was more than just its ohmic and spark gap resistance: it included the radiation resistance of the aerial system. A good radiator, therefore, as Lodge had pointed out, meant heavy damping and hence shortening of the oscillation and radiated wave-train. It was a problem for effective signalling. Sustained oscillation and good radiation were conflicting requirements.

Syntony

Eventually the problem was solved by the technique of syntony, or tuned coupled circuits, which also provided better selectivity. For this the underlying resonance principle had been demonstrated by Lodge in 1889. Marconi patented his 'syntonic' transmitting and receiving system in 1900: patent No 7777.

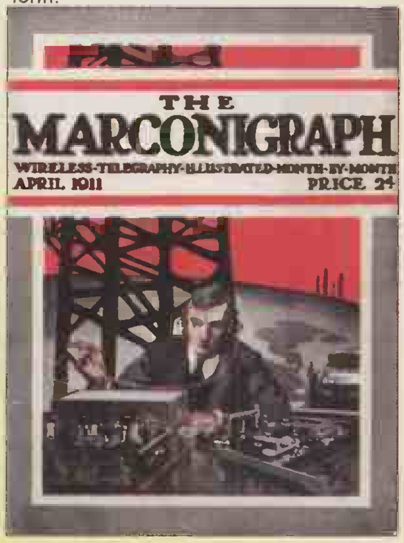
The 1896 patent, however, describes simple, open systems without tuning. Transmitting frequency is determined solely by the dimen-

The link with *Electronics World*

This journal, which has just completed 85 years of continuous publication, owes its existence to the wireless telegraphy company that was established with the commercial protection of the 1896 patent.

Founded as *The Marconigraph* in April 1911 (see the reproduction of the front cover), it was then mainly a house magazine, but aimed to "acquaint the lay reader with the latest possibilities in connection with this most marvellous invention" – at a price of 2 (old) pence per month.

In 1913 the magazine was sold to an independent publisher and became *The Wireless World*. When radio valves and components began to be utilised in other, non-communication, applications, electronics technology was born – eventually to subsume radio – and the journal started on the road to its present form.



Front cover of the first issue of The Marconigraph, which later became Wireless World and the present Electronics World.

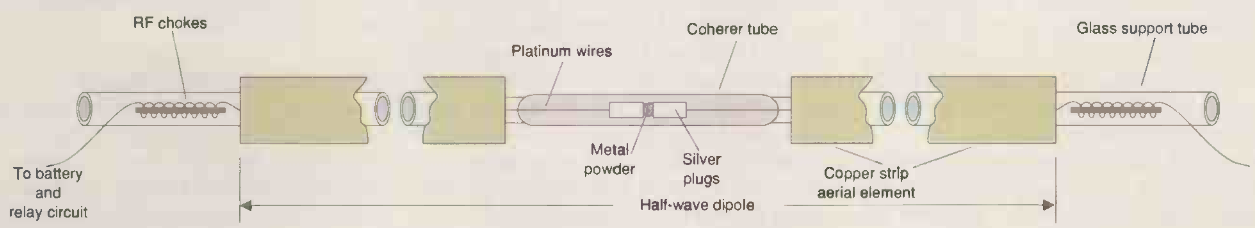


Fig. 2. Dipole receiving aerial with coherer between the elements. The coherer is connected to a battery and relay through two rf chokes.

sions of the oscillating and radiating elements. Though in practice the radiated spectrum is very wide. There are three kinds of spark transmitter, all using induction coils with vibrating interrupters pulsing the primary windings; and one kind of receiver, based on a coherer with resonating aerial elements connected to it.

Morse code signals are sent by a key in the pulsed primary circuit of the induction coil. At the receiver these are read by an ordinary telegraph instrument actuated from the coherer through a relay.

In one of the transmitters the radiator is essentially a Hertzian dipole formed by a horizontal array of metal balls providing spark gaps, as shown in **Fig. 1**. Other texts describe this as a Righi oscillator. The balls are solid brass, 100mm in diameter. The outer two gaps are about 25mm while the central gap is only about 1mm.

Obviously these spherical electrodes provide much of the oscillator's capacitance as well as being radiating parts of the dipole. Capacitance and dielectric strength between the two middle balls are increased by an oil dielectric held in a compartment. This 'increases the power of the radiation'. Oscillations of 25cm wavelength (uhf) are produced.

To improve the range and directivity of this radiator, the assembly is mounted at the focus of a cylindrical parabolic reflector, made by

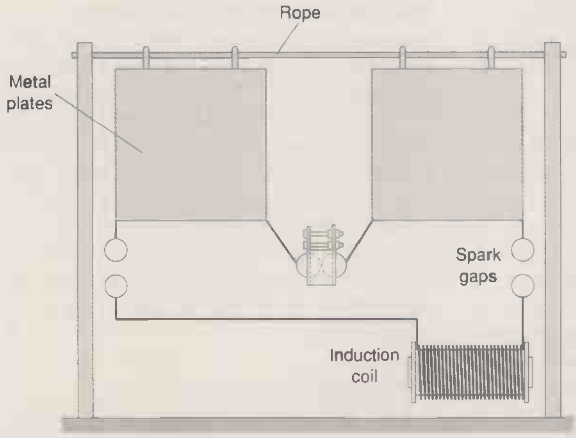


Fig. 3. Spark transmitter with dipole aerial formed by elevated metal sheets.

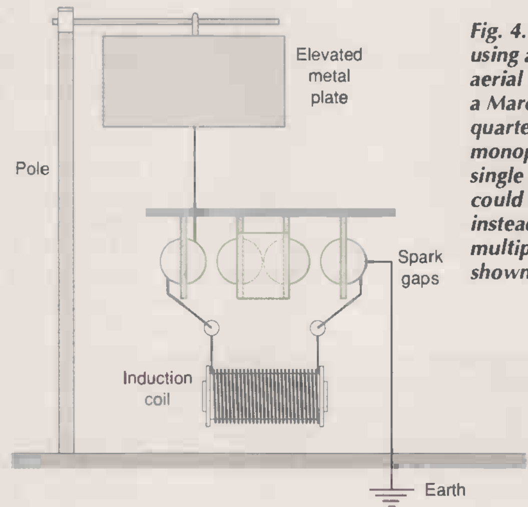
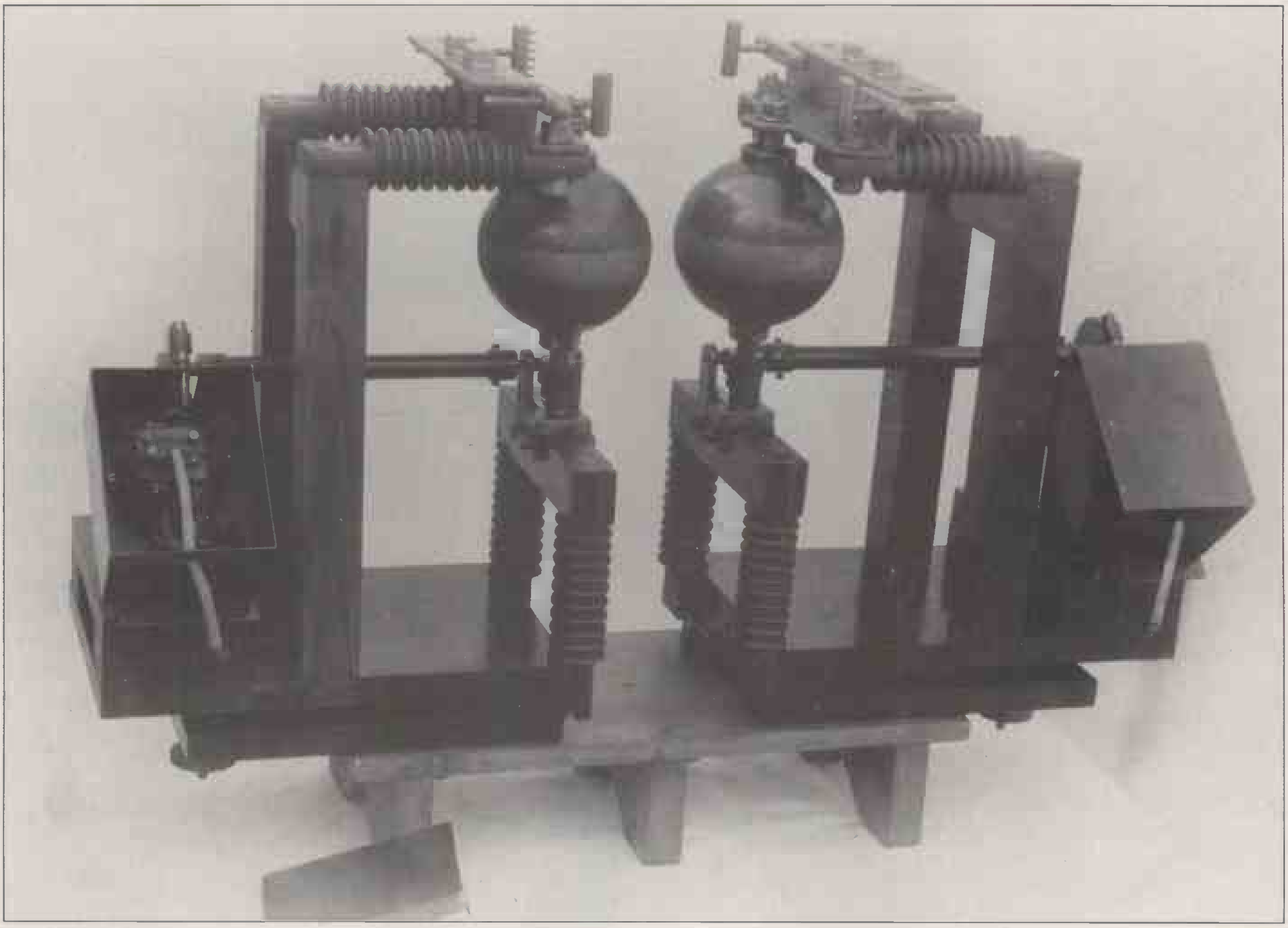


Fig. 4. Transmitter using an earthed aerial (later called a Marconi aerial or quarter-wave monopole). A single spark gap could be used instead of the multiple system shown.



Later spark gaps, like this 1905 example, had motors rotating the spheres to avoid the pitting caused by discharges all at one place.

bending a sheet of brass or copper. Fed from an induction coil normally giving a 25cm spark, the system achieves a range of over 3km.

Tuning the receiver with tin foil

Corresponding to this transmitter is a receiver with a resonating half-wave dipole, **Fig. 2**, placed at the focus of a similar reflector. Here the dipole elements are 12mm wide strips of copper, cut to the required length to tune with the transmission. The appropriate lengths are found with a separate tuning aid – essentially a resonator containing a tiny spark gap, formed by strips of tinfoil which are experimentally cut to various trial lengths.

Two chokes at the outer ends of the dipole provide high impedance to rf and isolate the aerial from the electrical wiring. This was done to concentrate the received energy in the resonator and coherer.

In the middle of this receiving dipole is a coherer, or what patent calls a 'sensitive tube'. This comprises a 38mm long sealed glass tube of about 2.5mm internal diameter, containing two silver contact plugs with a gap of about 1mm between them. In this gap lies a quantity of loosely packed metal powder or filings: a mixture of 96% nickel filings and 4% silver filings is recommended. The sealed tube is preferably evacuated.

The coherer is connected in a circuit containing a 1.5V battery and a relay. Initially the loose powder has low conductivity and passes very little current. When the dipole picks up a signal, however, the rf energy causes the filings to cohere and conduct strongly. The resulting current through the coherer then operates the relay and the telegraph instrument.

Mark tap space

Unfortunately the filings continue to cohere after the Morse dot or dash has ceased, so a small vibrating hammer or tapper, similar to an electric bell mechanism, has to be used to unstick the grains ready for the next Morse symbol.

A different kind of transmitter is illustrated by a diagram similar to **Fig. 3**. Two metal plates are suspended by insulators from a rope and connected through spark gaps to the induction coil to form a Hertzian oscillator. No reflector is used. From the description, the mode of operation is not clear, though obviously the two plates not only form a dipole aerial but also provide a lot of capacitance and hence radiated power. The larger and higher they are, according to the text, the greater the signalling range.

Finally the patent reveals the use of the earthed antenna – the Marconi aerial discussed above – in a transmitter, **Fig. 4**, and a corresponding coherer receiver. At both stations the single elevated metal plate is suspended from a pole, though kites covered with tinfoil are also successful. This system is advantageous where "obstacles such as many houses or a hill or mountains intervene between the transmitter and receiver."

Again Marconi reports that the higher and larger the antenna plates the greater the range achieved.

Start of a company and industry

Acceptance of this first patent in July 1897 provided the commercial basis for setting up a company that same month to develop and promote the Marconi apparatus. This was The Wireless Telegraph and Signal Company Limited, which eventually became The Marconi Company and finally part of GEC.

Some of the early demonstrations and communication achievements are described and illustrated in the *EW&WW* article 'Marconi Beginnings' in the January 1992 issue, on pages 74-76. ■

Further reading

A useful bibliography on the origins of radio is published in an article 'Guglielmo Marconi and Early Systems of Wireless Communication' by R W Simons, *GEC Review*, Vol 11, No. 1, 1996.

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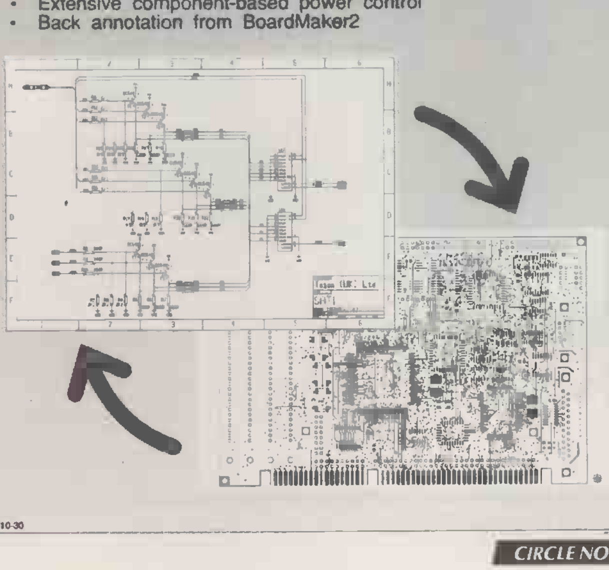

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Winner: best rf article '95

The article Demodulation – a new approach – on the following pages is winner of *Electronics World*'s 'Best rf article '95' award – a Hewlett Packard programmable signal generator priced at £4000. Some 30 entries were considered, representing articles both published and unpublished articles offered to *EW* during 1995 – which is why the judging took longer than planned. All were interesting and there was a healthy shortlist of contenders for first place. But Archie's work stood out in that it represents a technique that truly breaks new ground in the important area of demodulation.

Since the article's publication in the December 1995 issue, Archie has further developed his amplitude-locked-loop and is presenting a paper describing the technique's mathematical model at BSI 96 International at Chertsey on 4 June.

The US Army has been looking at the demodulation system for incorporation into their new pan-forces radio system called 'Speakeasy'. From their initial evaluation, they agree that the technology works "as advertised".

Additionally, DRA Malvern is using the analogue-locked-loop technique in advanced laser dopplerimetry to minimise co-channel interference.

Since publication of the article, eight advances have been made to the high-performance demodulator. Among these, the system's speed has been increased by a factor of five and overall dc coupling is being used to reduce cross-modulation products.

For his rf design article, 'Demodulation – a new approach', Archie Pettigrew wins an *HP 8647A* synthesised rf signal generator. Fully programmable and operating from 250kHz to 1GHz, this generator is designed for a variety of general purpose applications and semi-automated receiver test. With 300 storage registers and ten user-definable sequences – accessible from a remote keypad – the HP 8647A easily adapts to any test procedure. The generator features HPIB interface, a solid-state programmable attenuator and built-in am/fm modulation capability.

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Demodulation a new approach

Archie Pettigrew's new demodulator concept uses amplitude-locked loop techniques to produce significant improvements in the quality of fm and am reception.

The amplitude-locked loop was developed to overcome a number of fundamental difficulties which have existed since the inception of both amplitude and frequency modulation – am and fm.

With the radio spectrum becoming more crowded each year, and carrier frequencies moving inexorably higher, two basic problems with am and fm transmission become more obvious. Amplitude modulation becomes highly distorted when the carrier fades – or in certain cases, vanishes altogether. Frequency modulation becomes highly distorted and unintelligible when another fm signal arrives at the antenna at the same time as the wanted signal which is equal in amplitude and of a similar frequency.

Both these breakdown processes are caused by interference in the form of multi-path[1] Doppler or quasi-synchronous[2] reception. All these forms become worse as frequency of the carrier is increased i.e. as wavelength is shortened and/or as transmission becomes mobile[3]. By using an amplitude-locked loop and associated circuitry, many of these interruptions can be avoided, and more reliable communications achieved.

This article describes in detail the operation of two demodulators, one for am and the other for fm, using the amplitude-locked loop.

Amplitude-locked loop

The amplitude-locked loop, ALL, is the dual of the phase-locked loop, PLL. It works in the magnitude domain rather than the phase or frequency domain. It consists of a linear multiplier contained inside a high gain, high bandwidth servo loop.[4,5,6]

A phased-lock loop is similar in that it consists of a voltage controlled oscillator contained in a high gain, high bandwidth servo loop. **Figure 1** shows a diagram of the amplitude-locked loop[7].

Carrier from the intermediate frequency stage of the radio enters the ALL at the first port of the linear multiplier. The second port of the multiplier is set to a nominal value of unity. The modulated carrier passes through the multiplier to the modulus detector which accurately detects the modulus of the carrier down to white noise levels.

A dc reference voltage compares and subtracts the incoming modulus voltage and a difference or error voltage is generated, $e(t)$. This voltage is integrated and reversed in sign. Output of the integrator is added to the restoration voltage which sets up the operating conditions – or bias conditions – of the loop.

When no carrier amplitude is present, the loop is out of lock. The integrator drifts to its maximum voltage and the multiplier is at maximum gain awaiting an input. When the carrier appears, an initial transient occurs as the loop pulls into lock. Servo feedback causes the carrier amplitude at the output of the multiplier to be fixed or locked to an amplitude defined by the loop reference voltage.

Let a simple amplitude modulated carrier $v_1(t)$ be described as,

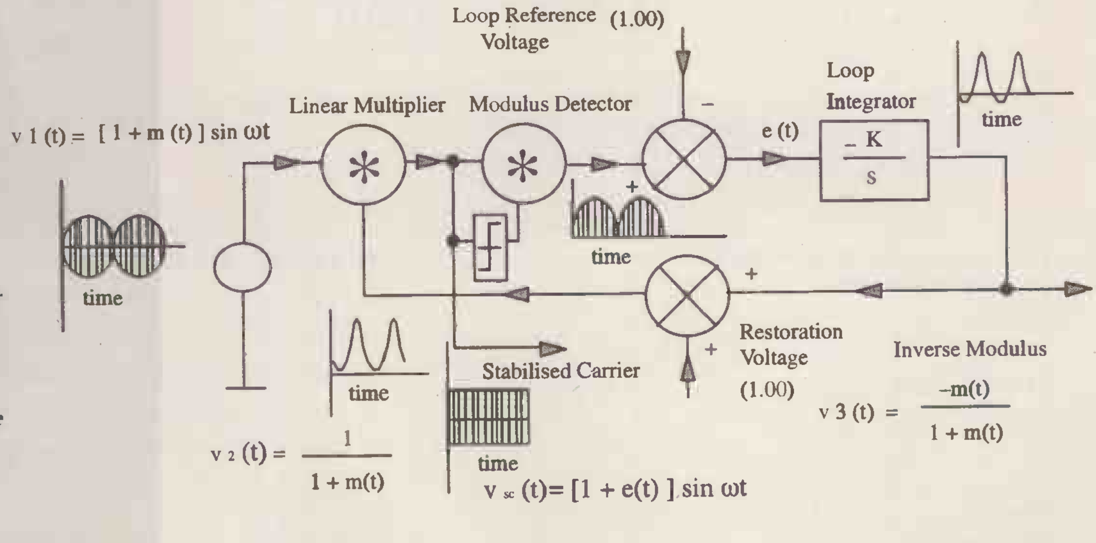


Fig. 1. Amplitude-locked loop consists of a linear multiplier, modulus detector and a high gain integrator. When the loop is closed, envelope variations of the carrier are reduced to insignificant proportions due to servo action and an error signal called the inverse modulus is produced.

$v_1(t)=[1+m(t)]sin\omega t$

where $m(t)$ represents the modulating function of time and $sin\omega t$ is the normalised carrier amplitude of ω radians per second.

After some mathematical analyses, a number of amplitude-locked loop identities become evident. Assuming that open-loop gain is sufficiently high that servo theory is valid, ie the value of K in the integrator is greater than 100 at the maximum frequency of interest, the stabilised carrier, $vsc(t)$, becomes,

$v_{sc}(t)=[1+e(t)]sin\omega t$

where $e(t)$ is the loop error voltage which becomes insignificant due to the high open loop gain. That is, $v_{sc}(t)=[10]sin\omega t$

Voltage $v_{sc}(t)$ represents a stabilised carrier with no envelope variations. Voltage at the second input to the multiplier must therefore be the reciprocal of the input modulation. As a result, $v_2(t)$ is $1/[1+m(t)]$ and $v_3(t)$ is $-m(t)/[1+m(t)]$ by subtracting unity.

Three signals have been obtained – the unmodulated carrier, the inverse of the modulus and the inverse modulus with the dc term removed. Unfortunately, there is no requirement to recover the unmodulated carrier in amplitude modulation. The demodulated signal is the reciprocal of the modulation which is a highly distorted version of the original signal. The signal at the integrator output is simply the reciprocal of the modulation but with an average value of zero. At first sight, nothing seems to have been achieved by this circuit so why investigate further?

Much the same arguments were used for the PLL when it was first suggested. For example, the PLL could easily have been replaced by a piece of wire and at a much lower cost etc.

Perhaps for the above reasons the concept of the ALL has never been investigated, even in the valve or tube era of electronics. If the ALL is not directly suitable for demodulation of am, can it be used to replace the limiter-filter in the demodulation process? Indeed it can as will be explained.

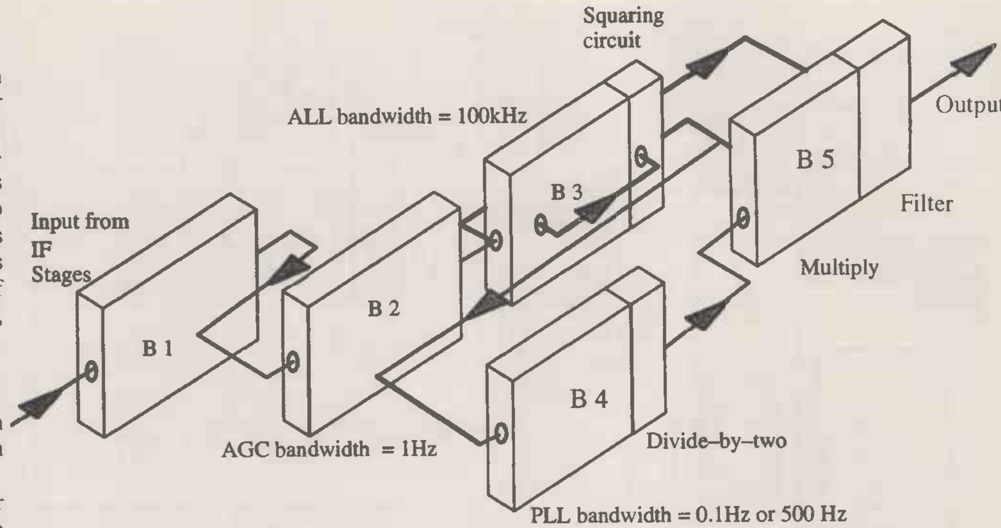


Fig. 2. ALL-PLL amplitude demodulator. The amplitude-locked loop alternates between in-lock and out-of-lock for strong and weak carrier signals. The PLL captures the carrier phase quickly but releases it slowly. A highly stable carrier is generated.

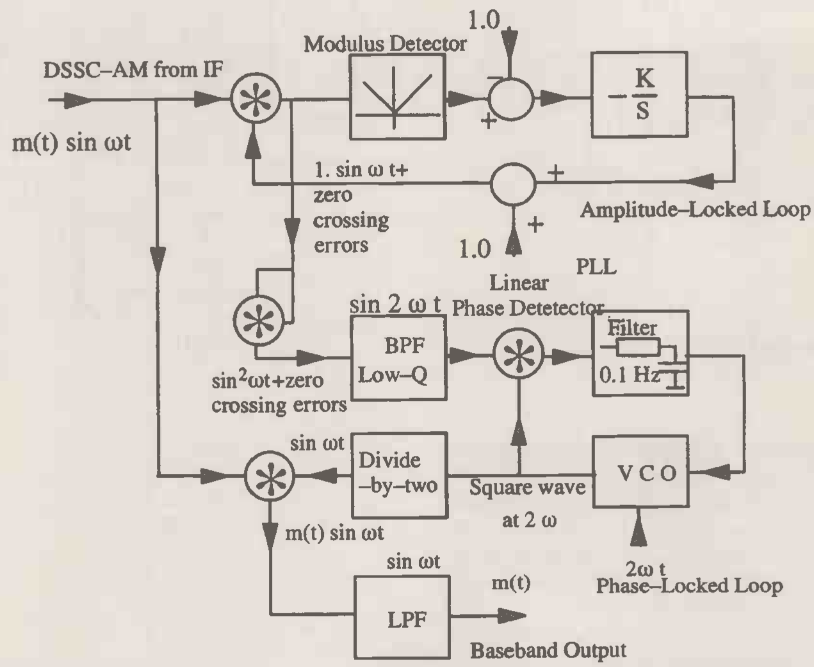


Fig. 3. Amplitude demodulator for double side-band suppressed carrier. The amplitude-locked loop generates a constant envelope from the input carrier. As the carrier approaches zero the amplitude-locked loop loses lock and the gain changes by 80dB. Phase-locked loop bandwidth is reduced by the same amount and synchronous demodulation is now feasible even in conditions of high noise.

Application to fm demodulation

When two fm carriers of equal amplitude are added, their envelope increases to twice the individual size and reduces to zero at the instantaneous difference frequency. This envelope variation will be eliminated by the servo action of the ALL. This is similar to the action of a hard limiter and a filter and fulfils the first requirement in fm demodulation – that am variations must be removed before demodulation.

A second signal is also available which is the inverse of the modulus of the two carriers. Could this second error signal be used constructively to improve fm demodulation?

Operating limits

Before continuing, it would be sensible to define the limits of operation of the first ALL unit. Starting with an intermediate frequency of 455kHz, amplitude and phase information is updated at twice the carrier frequency or 910kHz.

In a closed-loop feedback system, instability starts to occur at about one tenth of this frequency or 91kHz. So the ALL unity gain bandwidth was set to 91kHz giving an open loop gain at say 1kHz of 91 or 39dB. This was improved later by using a double integrator.

The dynamic range of the ALL was determined by the offsets and the characteristics of the linear multiplier, the *Exar 2208*. This was found to be to +20dB (10) to –6dB (0.5) or a linear lock range of 26 dB.

In practice, the ALL will track 26dB of amplitude variation up to a frequency of about 20kHz without significant error. This was found to be more than adequate for all narrowband fm speech channels. The lock-in transient is very short since the ALL is more linear than a PLL. Typically it was measured at about 4μs, i.e. the time required to reach 95% of the steady state value of stabilised amplitude.

Using a simulation package called *MATRIXx*, optimum circuit operation was established before any hardware was constructed. A much improved loop was designed using a double integrator with suitable phase advance for stability. This is described further in reference 8.

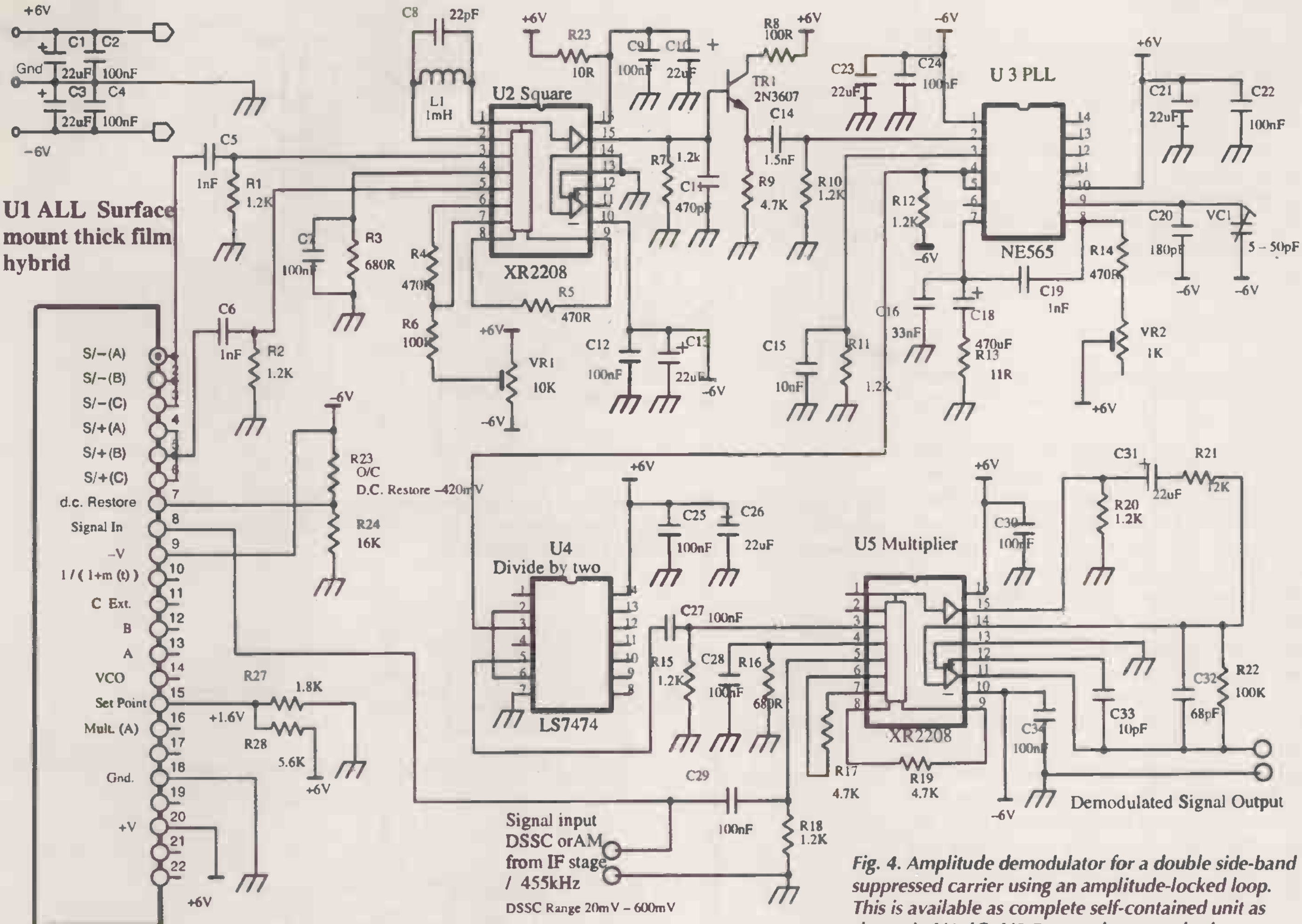


Fig. 4. Amplitude demodulator for a double side-band suppressed carrier using an amplitude-locked loop. This is available as complete self-contained unit as shown in U1. ICs U2-5 comprise a standard synchronous demodulator.

Applying the amplitude-locked loop

The first application of the ALL is to improve the amplitude modulated double side-band suppressed carrier. This represents the ultimate in carrier – or Rayleigh – fading since the carrier vanishes at every silence of the speech waveform, by definition.

The core of this problem is the recovery of a stable carrier. There is no carrier present during the silence between speech. The worst case occurs at the lowest modulating frequency and lowest amplitude of the signal.

Doppler effects may cause the carrier to be shifted by say 100Hz so that high-Q filters are not permitted due to their rapid phase changes at resonance. Should the system lose lock, then reliable re-lock must occur within say one cycle of the lowest operating frequency, say 300Hz, or in about 3ms.

The carrier recovery circuit must also be able to track frequency variations up to 100Hz to an absolute phase accuracy of less than say 45° error between the modulated carrier and reference carrier. Assuming that a PLL is available to regenerate the carrier at 455kHz, then two conflicting conditions need to be met simultaneously.

Since amplitude of the DSSC signal is continuously varying, the envelope must first be

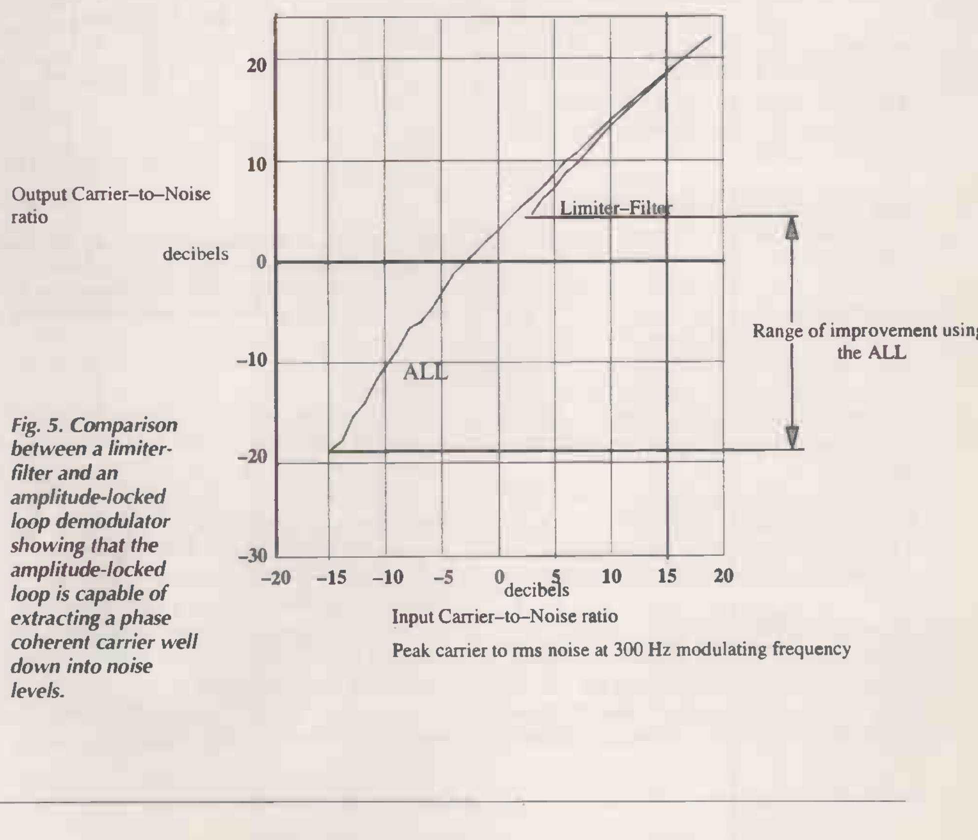


Fig. 5. Comparison between a limiter-filter and an amplitude-locked loop demodulator showing that the amplitude-locked loop is capable of extracting a phase coherent carrier well down into noise levels.

made constant. The PLL must have a wide capture and track range for fast lock-in and frequency tracking, yet it must have an extremely narrow noise bandwidth for stability during every speech silence.

The solution to these seemingly conflicting requirements is shown in **Figs 2** and **3** in block diagram form and in circuit form in **Fig. 4**. This could be could be done by limiting and filtering which would be successful at high instantaneous amplitudes. A major problem occurs at low amplitude and low frequencies with noise. Noise captures the limiter, the voltage controlled oscillator becomes unstable and the phased-locked loop loses lock. System failure ensues. If the limiter is replaced by an ALL, a different process takes place.

At high instantaneous amplitudes, the large negative feedback of the loop flattens the amplitude variations giving a constant envelope at the output of the linear multiplier. At low instantaneous amplitudes, the ALL drops out of lock since its track range has been exceeded.

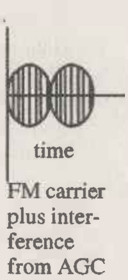
Gain of the 'loop' drops to the gain of the multiplier alone and not the combined gains of the multiplier, modulus detector and the integrator. At 300Hz, this represents a change from 80dB to 20dB. The noise level is not amplified, and in effect, the system closes itself down.

White noise is not permitted to overtake the signal, as would happen in a limiter. This is the advantage of the in-out action of servo feedback.

Carrier generation

A pure squaring device follows the analogue-locked loop to generate a coherent carrier at 2ω. When the ALL is out of lock, the PLL is being driven by a zero level carrier. Since the bandwidth of any linear PLL is a direct function of the input amplitude, its closed loop bandwidth drops to zero.

The voltage controlled oscillator free wheels on the long open-loop time constant of the PLL since there is no significant noise energy to cause perturbations. After a divide-by-two circuit, normal demodulation takes place.



Thus the PLL has effectively two bandwidths. The first is with signal present and the ALL in lock. With values suggested in Fig. 3 this bandwidth measures about 500Hz. When no carrier is present, i.e. with the ALL out of lock, there is no signal present at the input to the PLL.

The effective open loop gain of the PLL is reduced to zero assuming a linear phase detector.

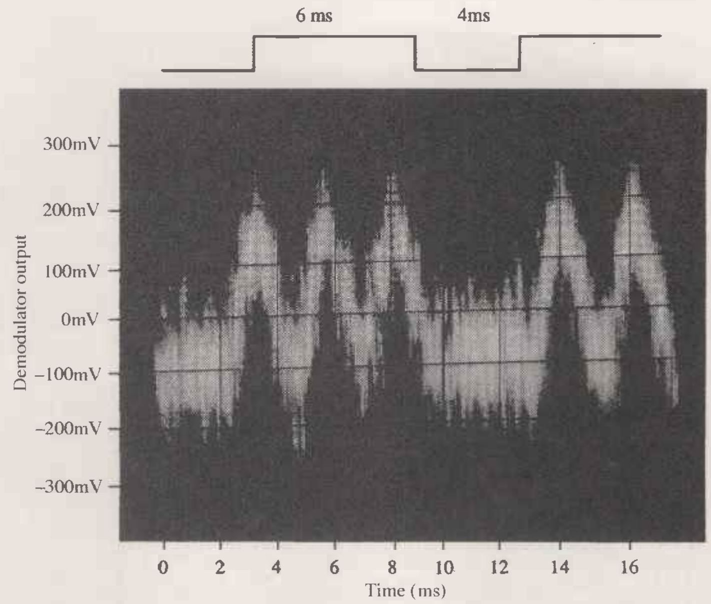


Fig. 6. Oscilloscope measurement of demodulated output showing a 300Hz signal gated on and off at 6 and 4ms intervals at a carrier-to-noise ratio of 0dB. Note stability of the noise during the period of zero level carrier. This is due to the amplitude-locked loop and the phase-locked loop both shutting down and awaiting the resumption of the signal.

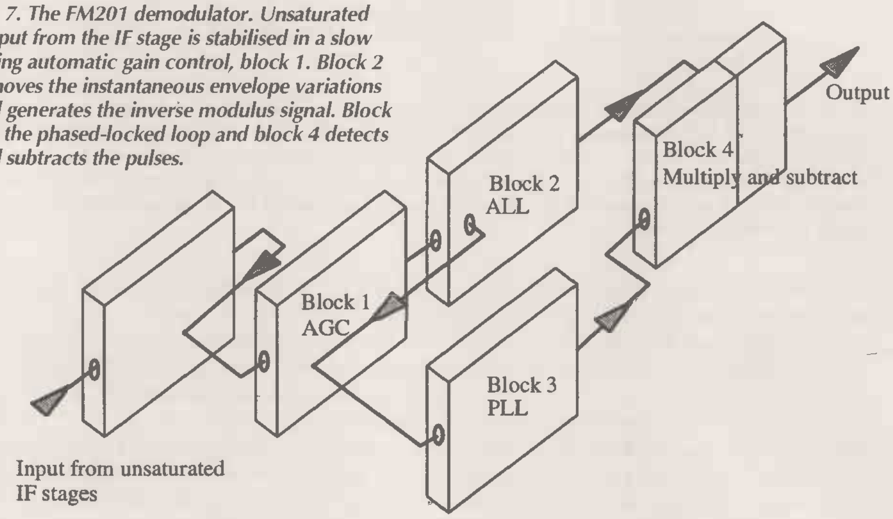


Fig. 7. The FM201 demodulator. Unsaturated output from the IF stage is stabilised in a slow acting automatic gain control, block 1. Block 2 removes the instantaneous envelope variations and generates the inverse modulus signal. Block 3 is the phased-locked loop and block 4 detects and subtracts the pulses.

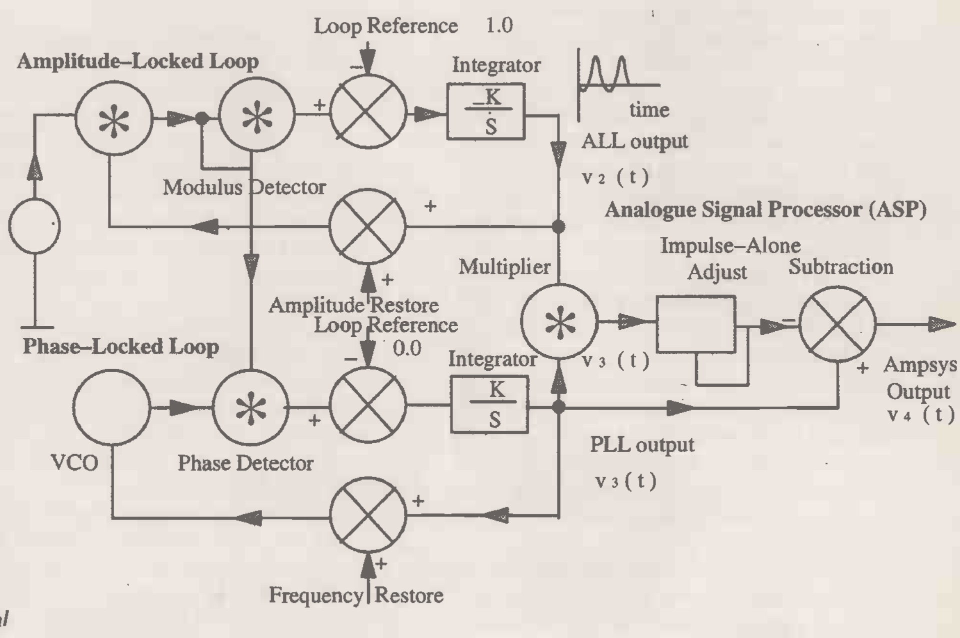


Fig. 8. Complete FM201 demodulator using an amplitude-locked loop, a phase-locked loop and an analogue signal processor. Inverse modulus from the amplitude-locked signal is multiplied by the phase-locked loop output to produce the impulse alone signal which is scaled and subtracted from the original phase-locked loop signal.

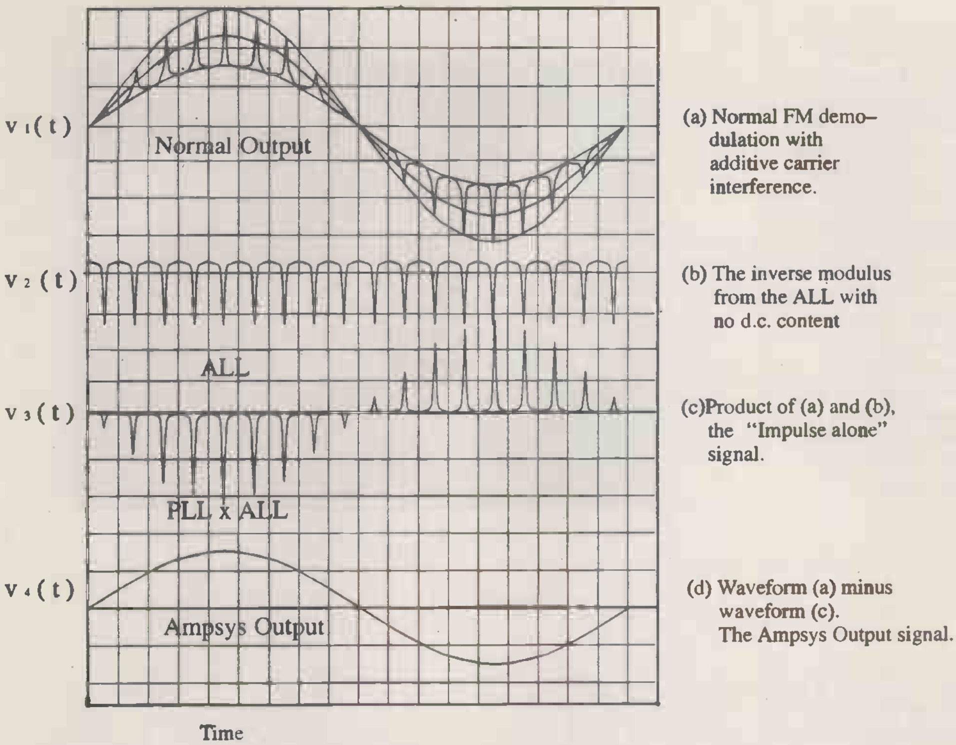


Fig. 9. Waveforms in the FM201 demodulator. The inverse modulus $v_2(t)$ is multiplied by $v_1(t)$ and subtracted from the phase-locked loop output to give $v_4(t)$. Fig. 9a).Normal FM demodulation with additive carrier interference – phase-locked loop output. Fig. 9b) inverse modulus from the amplitude-locked loop with zero average ie no dc content. Fig. 9c) shows the 'impulse alone' signal – product of the signals 9a) and 9b). Fig. 9d) final demodulated output where all harsh impulses or spikes have been removed.

Stability of the voltage controlled oscillator is then determined solely by the time constant of the filter following the phase detector. This can be made large ie of the order of one second.

Carrier stability is thus maintained due to this very long time constant. By use of the ALL, phase-capture transients are very short when signal is present and phase loss transients are long when the signal is absent. By this technique, the coherent carrier can be recovered reliably even during periods of poor carrier-to-noise ratio. The circuit diagram of this system is shown in Fig. 4.

The ALL is contained in the hybrid block U_1. The circuits which follow the ALL represent the normal synchronous AM demodulation technique, namely, a pure squaring device (U_2) followed by a narrow track range PLL (U_3), a divide-by-two, (U_4) and finally a synchronous multiplier (U_5).

Results obtained for this demodulator are presented in Fig 5. **Figure 5** shows the comparison between a demodulator using a limiter and filter in place of the ALL. Whereas the limiter-filter ceased to operate effectively at about 3dB carrier-to-noise ratio, the ALL circuit still maintained synchronism until well into noise. Cycle slipping occurs in both demodulators at about the same relative position but does not result in complete loss of intelligibility.

It is interesting to note that there is no threshold effect present as would be the case in fm or angle demodulation. The output signal-to-noise ratio tracks the input carrier-to-noise ratio in a linear manner.

Results obtained from the above demodulator exceeded the performance of the normal synchronous demodulator in that carrier recovery could be achieved down to and below unity carrier-to-noise ratios. **Figure 6** shows an oscilloscope trace of a 300Hz sine wave signal which is being gated on and off at 6 and 4ms intervals. Carrier-to-noise ratio with signal present was 0dB. Noise and carrier amplitudes were equal.

Due to carrier stability, system white noise is demodulated in a coherent manner. The PLL has an effective phase capture bandwidth of 500Hz and a phase release bandwidth of 0.1Hz. This phase capture-release phenomenon is a direct consequence of utilising the two in-lock and out-of-lock characteristics of the ALL and PLL simultaneously to make a near perfect am demodulator. This represents a major improvement in the state of the art on am demodulation.

This demodulator operates reliably and completely independently of the presence or absence of carrier. It is therefore ideal for the reception of am during multipath or quasi-sync. conditions.

FM demodulation

Frequency modulation is transmitted at constant amplitude. Any amplitude variation at the point of reception must be due to interference or noise acquired en route.

According to perceived wisdom, amplitude variations must be removed by hard limiting and filtering of the carrier on reception. If not, two forms of degradation will occur at the demodulator output. The first is due to envelope variation and the second to phase variation.

In reality, the fm carrier is degraded not only by naturally occurring phase noise but also by amplitude noise. This is converted to phase noise in the limiting process. These two processes combine as the input carrier-to-noise ratio approaches a low value of typically 12dB.

The catastrophic fm threshold effect begins and rapid deterioration of the output signal-to-noise ratio then follows.

This same effect causes fm reception to be rendered unintelligible if two fm transmissions arrive at the antenna at equal or near equal strength to each other – assuming co-channel frequencies.

The corrupting carrier may be another transmission – co-channel – or a delayed version of the wanted carrier – multipath. It could even be a version of the same broadcast from an equidistant transmitter – simulcast or quasi-sync reception. Harsh acoustic spikes are demodulated which are inband and cannot be filtered.

Capture effect

In the past, much has been made of the 'capture effect' in fm. Generally, this means that if one carrier is say 10% stronger than the other, say 1dB, then capture takes place and the weaker station is completely suppressed. This was the argument put forward by Edwin Armstrong the inventor of fm. It is true – but it is not the whole story.

The unwanted carrier is suppressed but not into silence, which would be ideal. On the contrary, the co-channel interference is demodulated into strident noise, or large impulses which are intolerable to the ear and destructive of all intelligible communication. So destructive is this interference that all fm transmissions start to break down in the region where either carrier is within 6dB of the other. This is sometimes called the 'distortion zone' – when its existence is admitted. The 'capture effect' is not an advantage but is in fact a major disadvantage of fm in a crowded radio spectrum.

Frequency modulation works well when;

- carrier strength is high,
- there is only one single carrier,
- there is no co-channel interference,
- there is only one direct signal path,
- modulation depth is virtually unlimited
- transmission power is virtually unlimited.

These conditions prevailed some fifty years ago, but unfortunately not in today's overcrowded spectrum.

Ideal requirements of the modern demodulator would be a circuit technique which would make fm demodulation linear at low carrier-to-interference ratios but still have the co-channel rejection properties at high carrier-to-interference ratios. Quasi-sync and multipath reception would then be improved by the addition of the intelligence in the carriers and co-channel reception would be equivalent to crossed lines in telephones.

The Ampsys FM201 demodulator

Using an amplitude-locked loop for the first time, an fm demodulator has been designed and tested which demonstrates the above requirements. It is designated the Ampsys *FM201*. Its block diagram is illustrated in **Fig. 7** and a system diagram in **Fig. 8**.

In the *FM 201* demodulator there are four separate processes or stages. The first process, after the normal intermediate frequency filtering, is to stabilise the wanted carrier and the interfering carrier to a fixed average value using a slow automatic gain control circuit. This process is necessary in order to present the ALL with a fixed average signal level.

The fm was originally transmitted as a fixed amplitude and the automatic gain control restores this long term average. Saturating limiting is always avoided. The automatic gain control block has a bandwidth of 10Hz.

In the second stage, block 2, the ALL removes all short term variations leaving the carrier similar to the output of a hard limiter and filter. This stabilised carrier is then applied to the input of the PLL, block 3, which is regarded as normal demodulation.

A second output from the ALL, the modulus reciprocal less the dc term, is applied to a multiplier in the analogue signal processing stage, block 4, Fig. 7. Output of the PLL is applied to the second port of this multiplier. A product is formed at the output of this circuit – the 'impulse alone' signal. 'Impulse' refers to spikes superimposed onto the baseband signal by the demodulation process.

This new baseband signal is scaled in size and subtracted from the original PLL output. Care must be taken to ensure that any phase delays through the ALL and the PLL are equal otherwise subtraction will not be possible.

A demodulated signal is created which is free of harsh spikes and is now perfectly intelligible even when the carrier and interference are identical in magnitude. A simplified version of the relevant waveforms is shown in **Fig. 9a-d**. Voltages $v_1(t)$ to $v_4(t)$ correspond to those marked on Fig. 8.

Worst-case fm reception

Figure 10 is an oscillograph of the demodulator output when the interfering carrier is located at the centre of the the intermediate frequency passband and is of equal amplitude to the wanted carrier. This represents one of the worst case conditions in fm reception. It would result in the carrier vanishing and doubling alternately at the instantaneous difference frequency. It is equivalent to a fade of infinite depth.

The normal output signal-to-noise figure is much less than zero and is unmeasurable by normal instrumentation. Acoustically, all intelligence is lost and the channel would be muted. With the *FM201* demodulator, signal-to-noise ratio rises to about 14 dB unweighted. This is acceptable in a communication channel and represents 100% intelligibility.

The link has been preserved, so avoiding the call being dropped. In normal demodulation when Gaussian white noise is added or when both carriers become weaker, distortion and noise effects become even more severe and generally intelligibility is lost just after the fm threshold point. This means that there can be a 'distortion zone' or failure gap as wide as 12dB. In simple terms this means that if one carrier is more than one quarter the size of the other at the antenna, failure ensues rapidly.

With the *FM201* demodulator however, the spikes are removed, as are the 'Rician' spikes due to Gaussian white noise. The net result is a much improved communication channel with almost 100% intelligibility well below threshold. Further testing has given the following observations.

- When the interfering frequency is offset from the centre of the passband, similar subtraction can be achieved by inserting an offset voltage at the input to the final multiplier. The interfering frequency however must be fixed.

- When quasi-synchronous reception occurs, baseband signals combine and an improvement in the signal-to-noise ratio of approximately 26dB is measured at the equal amplitude reception point. Multipath distortion causes a small reduction in signal-to-noise ratio.

- When two modulated carriers are present, the result is similar to that of a crossed line in a telephone. Although this is not ideal, it is preferable to complete loss of intelligence.

- With a very weak carrier, harsh spikes are removed and noise subjectively more acceptable. White noise can never be removed since there is never enough unique information.

- When the carrier-to-interference ratio is high, the 'impulse-alone' product diminishes rapidly since there are no envelope variations. The weaker transmission is suppressed as in normal demodulation and all beneficial characteristics of fm are retained, for example, quieting and co-channel suppression.

To summarise

A new circuit concept has been proposed called the amplitude-locked loop which can be used in conjunction with a phase-locked loop to improve the quality of fm demodulation.

By using the fundamental property that fm is transmitted at fixed amplitude, and that a unique relationship exists between the reciprocal of the modulus and the fm phase perturbations, a new signal has been derived called the 'impulse-alone' signal.

By a simple subtraction process this new signal can be used to eliminate spikes generated in fm demodulation. A fundamentally improved method of fm demodulation has been proposed which meets the criteria set out above for fm demodulation in today's overcrowded radio spectrum.

Two demodulators using the ALL have been built and tested and are available for evaluation purposes, from Ampsys, one for am demodulation and the other for fm.

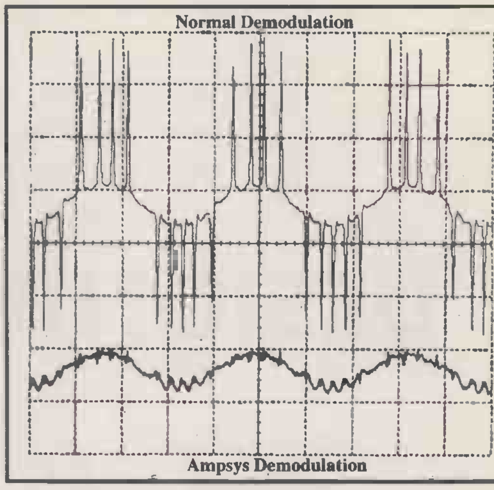


Fig. 10. These spikes could not be removed by any form of baseband filtering. At the interference-to-carrier ratio of unity the spike size is reduced by a factor of 20 fold, 26dB. Normally all intelligibility is lost. With Ampsys, demodulation is 100% intelligibility.

Acknowledgments

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Ignoring cost, nearly all power switching applications can benefit from replacing a bipolar output device with a power mosfet. But there is one very common application where this is still not the case. David Sharples explains why.

DESIGNING CRT *deflection*

The number of power applications that still have a bipolar transistor monopoly reduces by the day. The ingress of new technologies, such as high performance mosfets, igbts and power ICs, brings the humble bipolar transistor ever closer to the end of the road.

But there is one very common application where a bipolar high voltage transistor is the only viable power switch: tv and monitor horizontal deflection. As this situation is likely to continue for some time, while crt remains the dominant display technology, it is worth taking an extended look at this application.

Horizontal deflection circuitry

To understand the operation of the circuit shown in the panel consider the transistor turned on at time t_0, as shown in the waveforms in **Fig. 1**. DC voltage across the coil will result in a linear ramp in coil current:

$$\frac{dI_C}{dt} = \frac{V}{L_C}$$

This current, I_C, flows through the transistor to ground. At time t_1 the transistor is turned off. Turn-off is not instantaneous for a bipolar transistor and the current continues to rise for a couple of microseconds after the forward base current has stopped. This phase of operation is known as the transistor storage time: conduction is maintained by charge 'stored' in the device during the previous on time.

To turn a bipolar transistor off efficiently charge has to be extracted from the base, ie a reverse base current. When the base is depleted of charge to a level that restricts the flow of electrons from emitter to collector, the load will start to see turn-off. In this example, the load is coil L_c.

At the end of storage time, t_2, the voltage across the device, V_{CE}, starts to rise. This rise in voltage reduces the voltage across L_c which in turn reduces the current ramp. With optimum charge extraction during the storage time the transistor collector current, I_C will fall rapidly to zero in around 300ns.

As current in L_c cannot change so quickly, it is diverted to the flyback capacitor, C_{fb}. This current causes the voltage on C_{fb} to rise; L_c and C_{fb} operate as an *LC* circuit: sinusoidal rising voltage, cosinusoidal falling current.

At time t_3, current will be zero and a peak voltage will be reached. This is the peak V_{CE} on the horizontal deflection transistor.

Peak voltage now drops as the current is reversed and C_{fb} discharges. If diode D_2 was removed the system would become an *LC* resonant circuit. However, the diode has an important role.

At time t_4, the voltage reaches zero the current is a maximum, a negative going voltage forward biases the diode and the capacitor current is re-routed to the diode. The sinusoidal rising and falling voltage coincides with a polarity change in the coil current, this has then facilitated the flyback function.

With a negative peak current the beam is ready to start a scan at the left hand side of the screen. With a steady forward voltage drop across the diode, V_F, the voltage across the coil is constant yielding a linear ramp in coil current. As the diode/coil current approaches zero the transistor is turned on again. This early turn-on ensures a smooth zero-crossing as the coil current now becomes transistor current as the beam crosses the centre of the screen. And so the cycle continues.

Typical waveforms for the deflection transistor I_C, I_B and V_{CE} are shown in **Fig. 2**.

Typical device types

Two of the semiconductor devices shown in the circuit in the panel are standard commodity parts and two are unique to this application.

Primary switch transistor Q_1. In the circuit in the panel this is shown as a mosfet but in most television circuits a cheaper bipolar is used. For a low primary supply voltage an industry standard bipolar *BC337* or *2N7000* mosfet could be used. For high primary supply voltages industry standard types can still be used: *BF422* (bipolar) or *BS108/BSN254* (MOSFETs).

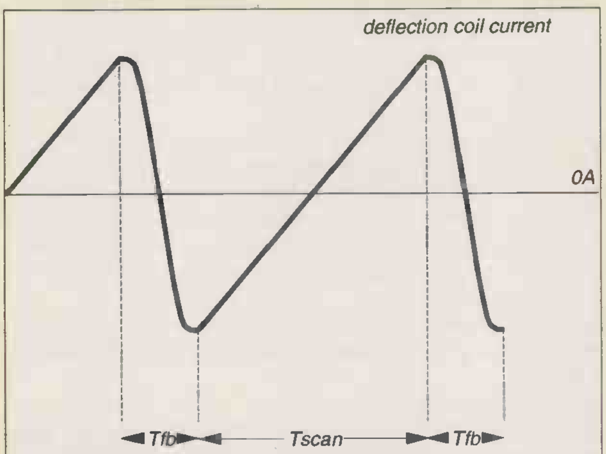
Turn-off diode D_1. Most small diodes will fulfil the requirements of this application. A well-used type is the Philips *BYD33D*.

Deflection transistor Q_2. Most deflection circuits have a peak flyback voltage of 1100-1200V; to allow for fault conditions the standard peak voltage of deflection transistors is 1500V. A small 14in television will only require a peak coil current of 2A. For the large screen, home cinema type tvs – up to 36in – peak coil current can be as much as 7A. Over specifying the current is not efficient in this application: a bigger piece of silicon may not be better than a correctly specified device.

Raster scanning basics

In the UK and mainland Europe, conventional tvs have a complete picture change 25 times every second, ie a change every 40ms. Each picture is made up of a series of lines, a 625 line system being the current standard. A change of 625 lines in 40ms implies 64µs per line. From this comes the 16kHz – actually 15.625kHz – horizontal, or line, frequency.

Each line is produced by the horizontal deflection of the picture tube's electron beam as it scans across the screen, left to right. The time the beam takes to scan from left to right is the scan time, t_{scan}. When the beam reaches the right hand

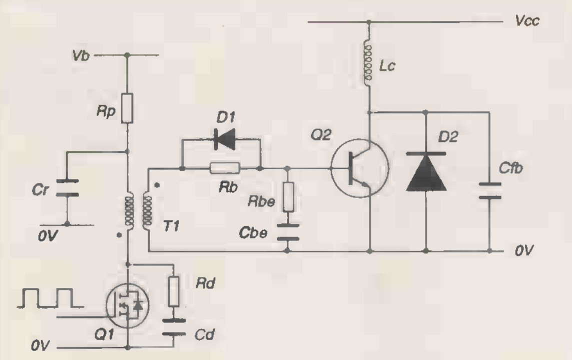


Current in the horizontal deflection coil. Time taken for the electron beam to scan from left to right of the screen, T_{scan}, is typically 52µs. Between scans, the beam takes 12µs to fly back, hence T_{fb}.

side of the screen it has to fly back to the left hand side before the start of the next scan. Time taken for the beam to fly back is the flyback time, t_{fb}. Typically, the 64µs per line is composed of a scan time, t_{scan}, of 52µs and a flyback time, t_{fb}, of 12µs.

Originating at the cathode gun at the back of the picture tube, the electron beam is accelerated to the screen by a high potential anode, typically 25kV. The beam is deflected horizontally during the scan time by a magnetic field produced by a deflection coil. This field is produced by a current ramp through the deflection coil, as shown above.

This current waveform can be produced in a variety of ways but there is one dominant circuit which is used in over 90% of television and monitor designs, this is shown in its simplest form in the diagram below.



Used in over 90% of monitor and television designs, this simplified circuit produces the current waveform required to scan the electron beam from left to right on the screen.

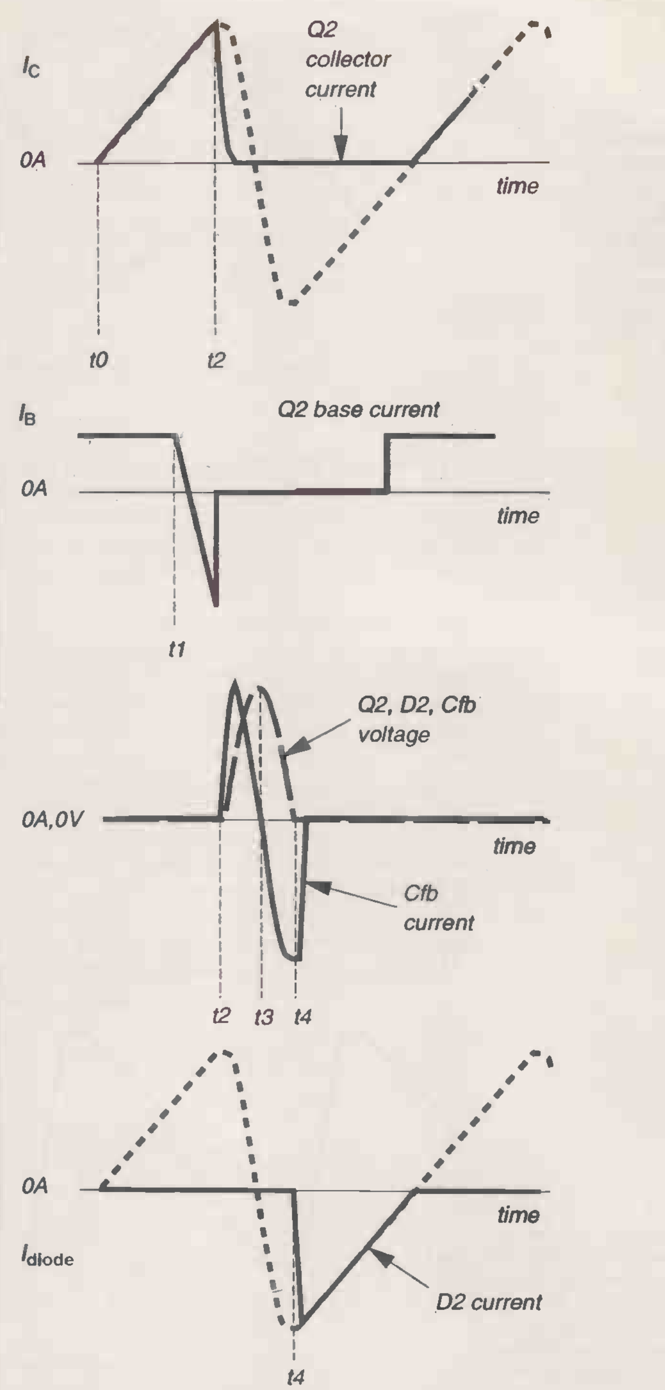


Fig. 1. Typical deflection circuit waveforms for the main circuit elements of the circuit in the panel.

Only a few of the world's major semiconductor suppliers offer a complete range of deflection transistors. Over 95% of the televisions produced will have a deflection transistor from one of these suppliers. Philips types range from the industry standard, and much copied, *BU508* to the new *BU2530AL*.

Damper diode D_2. As the damper diode is in parallel with the deflection transistor (see the circuit in the panel) it has the same peak voltage requirements. Also the coil current is symmetrical about 0A, therefore, the current requirements of the damper diode are the same as the deflection tran-

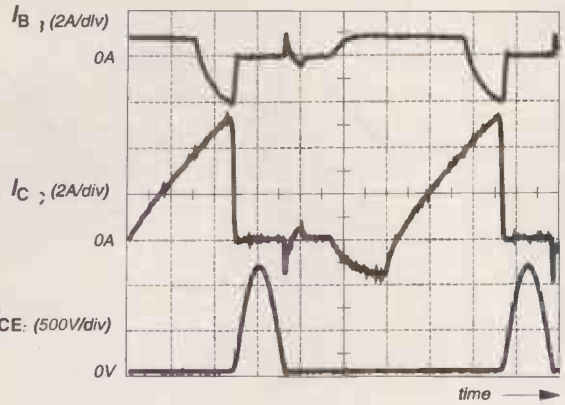


Fig. 2. Horizontal deflection transistor current and voltage waveforms found in a typical large-screen television.

sistor.

Products for this application are offered by most of the major semiconductor rectifier suppliers and some of the deflection transistor suppliers; including Philips Semiconductors. Philips types range from the glass bead *BY228* to the *BY459* in TO220 style packages.

East/west and S correction

To compensate for the curved surface of the picture tube, and obtain 'true' image reproduction, a number of corrections have to be carried out to the deflection waveforms; a linear ramp in coil current does not produce a watchable image. For horizontal deflection the two important correction functions to be aware of are S-correction and east-west correction

Given a typical display surface and a linear coil current ramp a pattern of equidistant lines would actually show as close packed lines in the centre of the screen and wide-spaced lines at the sides. The electron beam has to travel further to the edges of the screen than the centre.

To obtain an equidistant display, a ramp that is fast at the centre and slower at the edges is needed. This changes the shape of the coil current from a linear ramp to an S-shaped waveform, **Fig. 3**, hence the name S-correction.

S-correction is usually achieved by adding a capacitor in series with the deflection coil. In addition, compensation has to be made for the resistive component of the coil impedance. Coil resistance tends to shift the distortion to the right, and to compensate this a series negative resistance is required. This effect is achieved by a saturable inductance in series with the deflection coil.

The need for east-west correction arises from the fact that given the curved surface of the crt, the electron beam has to travel further per scan at the centre of the screen than at the top and bottom. And the amount of deflection is proportional to current. Adding this correction feature has the effect of applying an envelope to the deflection current with peaks for the centre.

Although the complete picture changes every 40ms, this is done by changing alternate lines so a frame changes every 20ms. Two frame changes produce a complete picture change. The frame frequency, or vertical deflection frequency, is then 50Hz. This 50Hz waveform is superimposed onto the deflection current to produce the east-west correction.

Modulated current is shown in **Fig. 4**. This is achieved by applying a modulated voltage across the deflection coil.

Generating eht

As well as being the power switch in the horizontal deflection circuit the transistor performs a secondary function – generating the extra-high tension, or eht. The eht circuit is a basic flyback converter power supply with a special high voltage transformer producing the 25kV required at the secondary windings. This transformer is commonly called the line output transformer, or LOT.

The horizontal deflection transistor provides the switching function to the primary of the LOT. For this reason the horizontal deflection transistor is also referred to as the line output transistor. Fundamentally, the eht function adds an offset of up to 1A to the total deflection transistor current, I_C.

Coil current now becomes symmetrical about the high-tension offset, therefore, the damper diode current reduces by this amount.

Adding the eht and correction functions to the basic circuit produces a modified circuit; a version of which is shown in **Fig. 5**.

IDTV, HDTV and monitors

So far, the discussion has been limited to European stan-

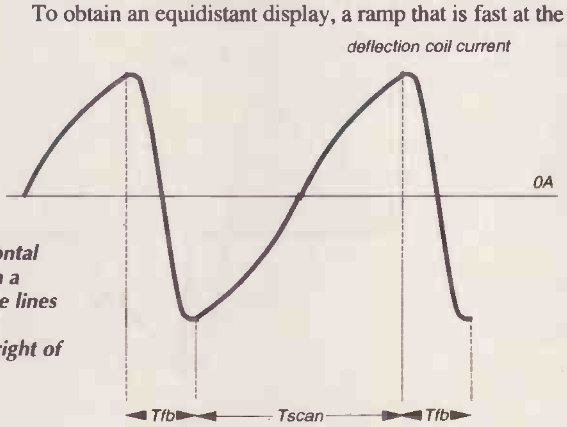


Fig. 3. Were the horizontal deflection coil fed with a linear ramp, the picture lines would be more widely spaced at the left and right of the screen than at the middle. S correction compensates for this.

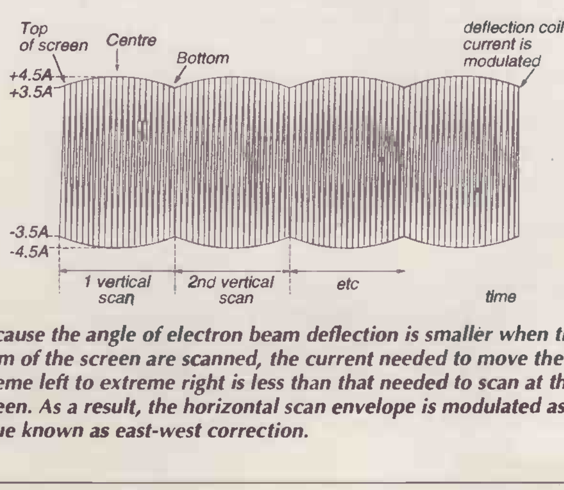


Fig. 4. Because the angle of electron beam deflection is smaller when the top and bottom of the screen are scanned, the current needed to move the beam from extreme left to extreme right is less than that needed to scan at the centre of the screen. As a result, the horizontal scan envelope is modulated as shown – a technique known as east-west correction.

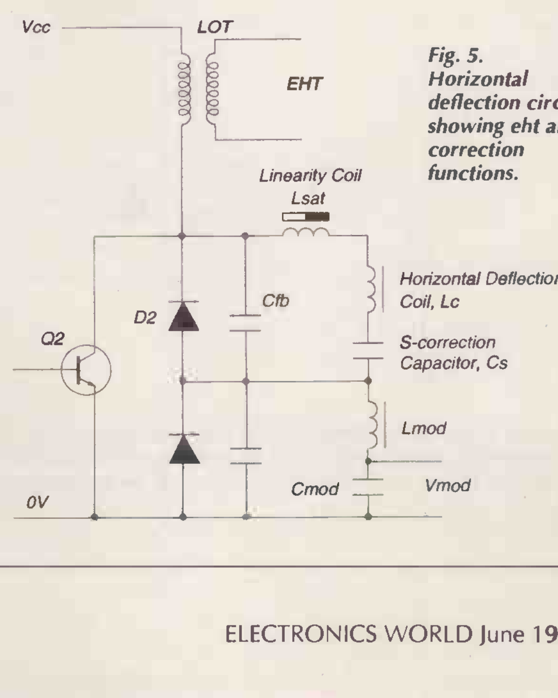


Fig. 5. Horizontal deflection circuit showing eht and correction functions.

dard television but, fundamentally, all of the above holds also for US, Far East TV, idtv, hdtv and monitors.

The 50Hz frame frequency of European tv follows the 50Hz mains frequency. For 60Hz mains countries, including the US and Far East, 60Hz frame frequency is used.

For a 625 line, 50Hz system the line frequency is 15.625kHz, often referred to as 16kHz. For 60Hz systems fewer lines are employed – frequently 525 lines – yielding a line frequency of 15.75kHz. This difference in line frequency is not significant to the deflection transistor.

New idtv systems offer 'flicker free' viewing with a 100Hz frame frequency, which is less detectable to the eye than 50Hz. In turn the line frequency doubles to 31.25kHz. This change is very significant to the deflection transistor.

Current proposals for hdtv systems indicate a 64kHz line frequency may be standard. Again this will have a further significant bearing on the deflection transistor selection. However, this application is unlikely to produce any new requirements for deflection transistors as a more taxing application already exists – pc and workstation monitors.

Monitors are now being produced that offer modes of operation that require line frequencies above 100kHz. Such sets are still required to operate at the common low end as well; VGA is 31.5kHz. All these applications are being met by bipolar deflection transistors in circuits very similar to that shown in the panel.

Ten years ago, not many pundits would have predicted the use of bipolar power transistors in high volume, 100kHz plus switching applications into the 21st century. But this is almost certainly the case with horizontal deflection applications.

Specifying the deflection transistor

In the simplest terms, the device should provide the functions outlined above with minimum dissipation. The device should also be able to survive any fault condition that may occur.

In a cost driven business like domestic television and pc monitors, the device/circuit costs are also important. The following notes equate these requirements to device characteristics.

On-state. When the device is on, ie passing positive collector current, I_C, the collector-emitter voltage drop, V_{CE}, must be as small as possible. Any voltage drop will modulate the voltage across the deflection coil and either cause

Optimising base current

These steps outline how to match the deflection transistor's I_B waveform to loading, I_C.

- Measurement equipment: oscilloscope, 2 calibrated clamp-on current probes and 1 calibrated and compensated 100:1 voltage probe.
- Set I_B level (just before I_B turns off) to be 1/5 of the nominal peak I_C level.
- Set peak $-I_B$ level to 1/2 of the nominal peak I_C level.
- Observe I_C and I_B waveforms, see **Fig. 6**. The I_B waveform should be essentially flat during the on-state with a linear slope to $-I_{Boff}$.
- Observe V_{CE} and I_C waveforms during turn-off to when I_C reaches zero. Waveforms for an optimised base drive are shown in **Fig. 7**.
- Observe the V_{BE} waveform; this should have no positive ring during flyback with an off-state level between –1V and –5V.

Once the principal operation has been established, the base drive should be optimised.

- Obtain high and low h_{FE} samples from the supplier. These will represent the production spread for a particular device.
- Additional equipment for thermal tests: calibrated heatsink (R_{th}≥15K/W for 16kHz tv), heatsink temperature measure (Eg thin-film thermocouple between device and heatsink or infra-red detector), ambient temperature measure.
- Determine application minimum and maximum load conditions. In a tv these conditions could be forced: min. brightness and contrast, min. picture width for minimum load; maximum brightness and contrast, maximum picture width for maximum load.
- For high and low h_{FE} devices record the steady-state heatsink and ambient temperatures for both minimum and maximum load conditions. Allow at least 15 minutes for the system to stabilise before taking temperature measurements.
- Power in the device can be calculated quite easily:

$$Power = \frac{Ths - Tamb}{Rth\ hs - amb} \quad \text{where,}$$

$R_{th\ hs\text{-}amb} \geq 15K/W$
$T_{amb} \approx 25°C$
$85°C \geq T_{hs} \geq 45°C$ (typically)

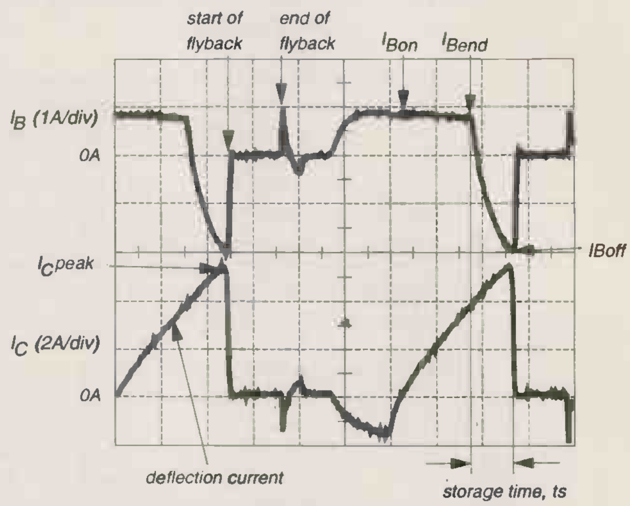


Fig. 6. Characteristics of the horizontal deflection transistor's collector and base-current waveforms after base-current optimisation.

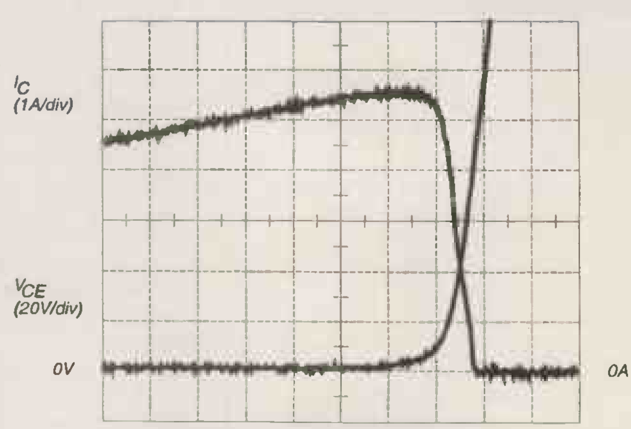


Fig. 7. Horizontal deflection transistor collector current versus collector-emitter voltage during turn off.

Fault finding in the deflection drive

Consider a 16kHz tv found to have a failed deflection transistor. Replacing it with an identical type restores full set functionality. If the picture shows some visible distortion then the chances are that there is a fault in the 'load' side of the deflection transistor, ie something causing a change to the I_C.

If, however, everything appears ok there may still be a problem with the drive that does not immediately result in device failure. For 16kHz television, a typical deflection transistor should dissipate less than 2W which means that the device can run in free-air with a 25°C ambient. This can be tried in the workshop. If free-air operation leads to device failure or a visible distortion the drive circuit needs to be re-optimised.

This technique will not, of course, resolve the failure if it was caused by a single overstress event. These failure modes could be the result of lightning induced picture tube flash, or interference from some other source of electromagnetic radiation. This type of failure mode cannot be diagnosed easily.

a visible distortion on the screen or require some additional correction.

During the on-state the device should be operated in the 'saturation' region of the transistor operating area.

Off-state. The device must be able to withstand any voltage applied across the collector-emitter terminals when there is no positive drive.

Switching. The transition between on-state and off-state must be achieved quickly and without unnecessary dissipation. This is the most critical feature of operation with regard to the device requirements. Unfortunately, the switching characteristics of power devices are very circuit dependent. An appreciation of the interacting variables is essential if an optimised design is to be produced. The 'Base drive optimisation' section offers an empirical path through the maze of information surrounding bipolar horizontal deflection switching.

Using device data

Semiconductor companies usually adopt formats for data which have evolved from in-house rules laid down many years ago. It can be difficult to relate much of the published data to the requirements of the application. But, there are vital pieces of information that can be extracted.

The first parameter to check is peak voltage – the largest voltage value in data. This can be expressed as V_{CES}, V_{CEX}, V_{CEV}, V_{CER} or V_{CBO}. For a solid-state physicist there are interesting differences between these parameters, but for a circuit designer all these can be viewed as the same. Most televisions of 21in and above, have a peak flyback voltage in normal running of 1100-1300V, in which case a 1500V peak voltage device is required.

There are no significant differences in the peak voltage characteristics of devices from different suppliers. This is the simplest data to comprehend.

A lower voltage value, V_{CEO}, is also often given in data. The subscript 'O' means the base is open circuit. Because the base is never open circuit in a deflection circuit, V_{CEO} is not of prime importance.

Glossary of terms

Deflection transistor parameters

I_C	collector current
V_{CE}	collector-emitter voltage
I_B	base current
I_{Bend}	base current, end of on period
$-I_{Boff}$	peak reverse base current
V_{BE}	base-emitter voltage
h_{FE}	current gain: I_C/I_B

Other abbreviations

EHT	extra high tension
HVT	high voltage transistor
LOT	line output transformer
R_{th}	thermal resistance

The second parameter to check is recommended operating current, which may not be too easy to find. Some suppliers give an I_{Csat} value – ie the I_C in saturation – in the summary at the top of the data sheet. For other suppliers the value may have to be extracted from another characteristic.

All suppliers quote either V_{CEsat}, h_{FEsat} or some switching values for a given I_C: this can be taken as the I_{Csat} value. The I_{Csat} value is determined by the chip size and hence has a large influence on the device cost.

There are two possible pitfalls when comparing I_{Csat} data: the operating frequency and 'specmanship'. A device specified at 4.5A for 64kHz operation in a pc monitor will have a bigger chip than a device specified at 4.5A for 16kHz operation in a tv. Also, some devices are over-specified on I_{Csat}. If some devices were operated at the I_{Csat} recommended in data they would have to be bolted to a very large, water-cooled heatsink. This is not practical for tv applications.

The only other relevant specifications are the maximum junction temperature, T_{jmax}, which is usually 150°C for bipolar deflection transistors, and the thermal resistance values. These specifications are required for base drive optimisation. Initially, at least, all other data is irrelevant.

Base drive design

Base drive design can only be optimised empirically. Advances in circuit simulation models fall short in this application: the available device (HVT and diode) and component (LOT) models are insufficient. This situation is unlikely to improve much in the next five years. Industry standard bipolar HVT models are not possible as the different construction of a 1500V, 5A, 64kHz device from supplier A will require a different drive from a 1500V, 5A, 64kHz device from supplier B.

The bipolar HVT is a current driven device so base current is the important waveform to analyse. A successful design will have matched this I_B waveform to the load (I_C waveform). The method, with a few 'rules-of-thumb', is outlined in the panel 'Optimising base current'.

For small screen tv, with an optimised drive, the power should be 2W, or less. For the largest tvs the power could be as high as 5W in the extreme load case.

From the power, the device junction temperature, T_j, can be calculated. Thermal resistance between the junction and the heatsink, $R_{th\ j-hs}$, will be between 2K/W for a large, non-isolated device to 5K/W for a small, isolated device. So,

$$T_j = T_{hs} + (Power \times R_{thj-hs})$$

A good rule-of-thumb is that the T_j is 10°C higher than the heatsink temperature.

The standard $T_{j(max)}$ for bipolar deflection transistors is 150°C, however, it is not good practice to use this as the limit in the above experiment. The thermal analysis has to be good for a complete production program so it is usual to inset the desired $T_{j(max)}$ to a lower value, typically 110°C. This should result in the elimination of any thermal failures during the production run of a tv model and enhanced reliability for the horizontal deflection stage.

Using a small heatsink compensates for not carrying the tests out at an elevated ambient. In the laboratory, the tv may have the back off and the main pcb may be exposed to freely circulating air. In domestic use the set will be placed usually with its back to the wall in the corner of a room. Heat flow in these two situations is significantly different, so some allowance must be made for this in the laboratory measurements. ■

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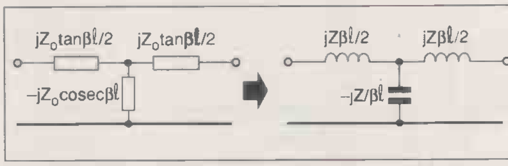
Sutton, Surrey, SM2 5AS**

Cable shunted

Although Ben Duncan's analysis of loudspeaker cables is highly interesting, it is evident that a shunt capacitance of 228pF (impedance greater than 10kΩ) cannot have any effect on a low impedance load. Indeed, if the amplifier were current driving, the cable modelled would have no effect at all.

A T-network is an excellent approximation of a transmission line at low frequencies (see figure) by linear approximation of the trigonometric functions. The total inductance and capacitance per metre in this case are the same as the intrinsic inductance and capacitance per metre of the transmission line.



A T-network is an excellent approximation of a transmission line at low frequencies.

The inductance parameter seems to be measured at cut-off to a 5.6Ω load, i.e. at about 1MHz. The corresponding capacitance at that frequency must be about 60pF (or else the dielectric constant is as high as 10.2).

If, due to increasing skin depth, the characteristic impedance becomes much smaller at lower frequencies, the inductance must correspondingly decrease so as to make $LC=1/c^2$ constant. Am I right? Otherwise there would be dispersion, i.e. lower-frequency waves propagating slower, but dispersion has to do with the dielectric which is relatively constant at low frequency. I couldn't find any loudspeaker cables hanging around, so I refrained from making the measurements myself.

Michael Williams
Jerusalem

Is oxygen to blame?

I read with great interest Anthony Hopwood's account of Prof. Henshaw's ideas on the causes of some cancers and leukemias in humans, in the April issue. I am sure some of these diseases can result from the causes mentioned, but only very few due to direct damage by alpha particles on human tissue.

I have suffered both these dreadful diseases myself, and have worked for 26 years on the first cyclotron in the world to be built in a hospital for medical research. There, alpha particles and deuterons were accelerated up to 15MeV. Even though several of my colleagues died of cancer, I do not believe the alphas caused direct damage to body tissue.

I think the causes of large number of victims of radiation combined with high voltages is best shown by going back to my first employers in 1932. They were two brothers who in the twenties manufactured cold cathode, gas focussed X-ray tubes. They had diversified into making architectural lighting and neon signs. My job was to gas fill these signs.

The brothers, as did many early X-ray pioneers, both died of cancer. Others from Madam Curie onwards died of leukemia. All these people had one thing in common with people living under power lines and getting either cancer or leukemia – they all breathed air that had simultaneously been exposed to a high voltage and some sort of irradiation.

Thus the air all these people were breathing was likely to be ionised, and since oxygen is taken up some thirty times more than any other elemental gas, it seems to me that the oxygen that was breathed had a charge of +15eV instead of the normal oxygen charge of –2eV.

Now because radon has such a large mass it cannot be freely accelerated at normal temperature and pressure. This is because of its short mean free path, and since it is inert it cannot be attracted chemically.

However the tiny electron which is so vital in electron transport system in metabolism will be accelerated and increased greatly in number by the Townsend avalanche effect. In all aerobic organisms – those that require O_2 – electrons find their way back to the ultimate electron acceptor, oxygen.

While oxygen may be the breath of life, could ionised oxygen be the death of you?

Leslie C. Baker
Dorset

Delayed reflections

I was intrigued to read Mr Russell's article on Transmission lines in *Electronics World* March issue. I designed and manufactured the *MDN2484* 8μS/8K delay line that you describe, in about 1965. Lexor Electronics of Coventry supplied these things mainly to the English Electric Company.who were Anglicising an RCA Computer and acquiring an interest in the LEO computer set up by J. Lyons. We designed a whole range of delay lines for them. Later the company became English Electric.

The article analyses the basic parameters correctly. However Mr Russel makes no mention of the factor which could possibly foul up the results if not taken into account.

Simply stringing together a cascade of *Ls* & *Cs* gives you a 'Constant K' line. This has a group delay characteristic from hell. Delays at low frequencies will be much less than those at high frequencies. Therefore when you double or otherwise multiply frequencies, the apparent wavelengths and thus nodal relationships will not be as expected.

Lexor delay lines were mainly designed for time-domain – pulse – operation. They were used in computers for equalising the delays through various diverging and converging paths in the computer, and a major third parameter following delay and impedance is overshoot and its opposite, undershoot. These are evinced in response to a pulse input.

Briefly, when undershoot and overshoot are equal, then all frequencies within the pass-band of the delay line (it can be considered as a type of low-pass filter with a Gaussian response) are delayed by the same amount.

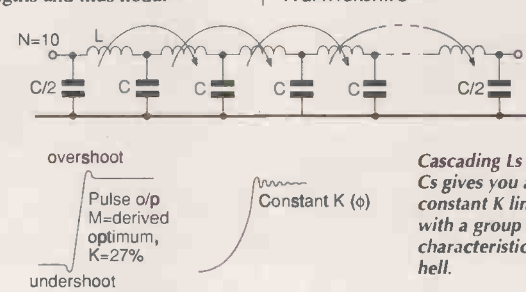
In order to achieve this within the design, you have to provide for magnetic coupling between adjacent sections of the line. Moreover the sign of the coupling should be positive between adjacent section and negative between alternate sections in order to avoid reflections (poor swr) at the highest frequencies.

In the *2484* series, this could not be contrived due to physical constraints, and all couplings were positive. Since the units were employed solely in the time-domain however this was not a problem.

The optimum coupling in a classic 'm'-derived design requires a 'K' of approximately 27%. This is managed in the *2484* series by winding the coils on ferrite 'cotton-reel' bobbins, and arranging them axially with a closely controlled spacing. Too close results in group delay negative with frequency, and *vice-versa*.

Values up to 500ns/560Ω are available in 14 pin, 0.3in DIL form these days. However, we still supply them all to order.

J.C. Pledger
Active Electronics Labs (tel. 01926 484050)
Warwickshire



Cascading Ls and Cs gives you a constant K line with a group delay characteristic from hell.

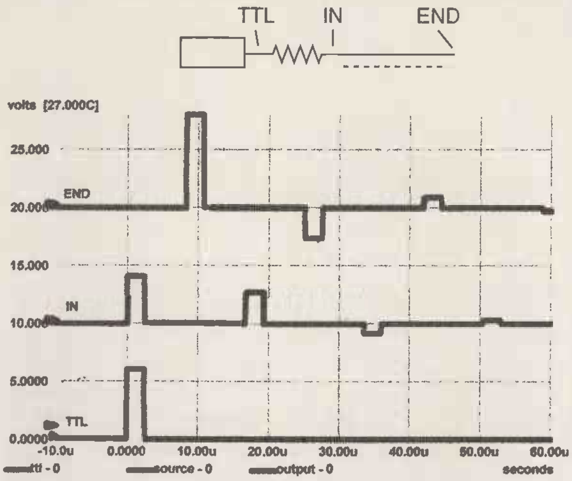
Ouch!

I would like to make it clear that Bill Russell's April 1996 article on transmission lines has used the ttl devices output for the top trace in Fig. 6. The actual input of the transmission line shows a pulse after 16.8μs. The amplitude of this pulse is 2.6V since a third of the returning 4V initial pulse is inverted and reflected back along the line.

The other nit I would like to pick at is; has Douglas Self actually measured his distortion levels with – to use an objective term – music? Music frequently contains peaks that may exceed five times the rms level. Many low distortion amplifiers use high voltage power supplies to supply these short duration peaks.

For uncompromising audio purists I suggest they bridge two of Self's amplifiers together and suffer a 3dB loss in the wallet!

Andrew Pate
Surrey



Spiceage simulation of Transmission Lines article Fig. 6 (April 1996 issue) for a TTL signal, a 4kΩ source impedance and no load.

No contest

In response to the 'challenge' in *Letters* in the May issue, Allen Wright appears to have misunderstood the nature of scientific enquiry. In the famous example, the hypothesis 'All swans are white' is disposed of forever by seeing one black swan. It is not necessary to look at more black swans in different ways to confirm the finding.

Faced with the rather less plausible hypothesis 'All copper conductors are composed of 10mV diodes' it is only necessary to show once that this is not true. I think that my experiment reported in the March '96 issue of *EW* is proof positive that magical 10mV diodes do not and cannot exist in solid copper. Further evidence is given by my *JAES* paper 'Granularity Distortion' which probed the matter down to the –150dBu level[1].

As far as I can gather, Mr. Wright's own hypothesis seems to be 'Thinner speaker cables sound different, and I think they sound better, so this must be because there are fewer magic diodes, as there is less total weight of copper.' Mr. Wright assumes – apparently for no other reason than because he wants to – that any change in subjective quality must be due to magic diodes, and that the highly unscientific procedure he outlines will 'prove' it. It is, I hope, unnecessary to point out the gaping holes in the logic here.

If an audible thin-cable effect exists, then I suggest the reason is as follows: single-strand cable will have a much higher resistance than normal speaker cables. The extra resistance means that the speaker impedance curve will be partially superimposed on the basic speaker/room frequency response. These extra response irregularities – which will not have been anticipated by the speaker designer, who will have assumed that his brain-children are to be driven by a low-Z source – may or may not make the overall sound better according to unguessable subjective criteria.

It may well be that a listener could convince himself that the result is greater clarity and lesser distortion; but he has no right to then state that the difference is due to mysterious effects when a very obvious explanation is right under his nose. Bring forth Occam's Razor.

Mr. Wright makes no mention of double-blind A/B testing in connection with his assertions, so I assume they were conceived under informal listening conditions. I therefore decline to accept his statements about enhanced clarity and reduced distortion.

While I can only judge by the title, I can well believe that any book entitled 'SuperCable Cookbook' would upset a lot of people, especially those who feel that technical books should preferably contain facts.

1. 'Ultra-low noise amplifiers and granularity distortion' *JAES* Nov 1987, pp 907-915.

Douglas Self
Idmiston, Herts

Caller who?

I would like to raise a few points related to Segaran's Caller ID article in the April issue. Enhancement of the service to deliver the caller's name is on trial, I believe with 400 users in Edinburgh, and with good results. Users can specify information sent in the name field; apparently most prefer to send first names only.

In my experience, the 'number unavailable' message relates not to phones on older exchanges but to those on catv networks, confirmed by asking the caller. This seems to imply that while catv networks support their own caller ID system they are incapable of transmitting Caller ID to BT's network. This is pathetic.

Mobile phones usually register as unavailable – but not always. Calls from ex-directory lines are not delivered as 'number withheld' by default; this must be specifically requested. Most of my 'number withheld' calls are from businesses whose numbers are advertised in the national press; this baffles and infuriates me.

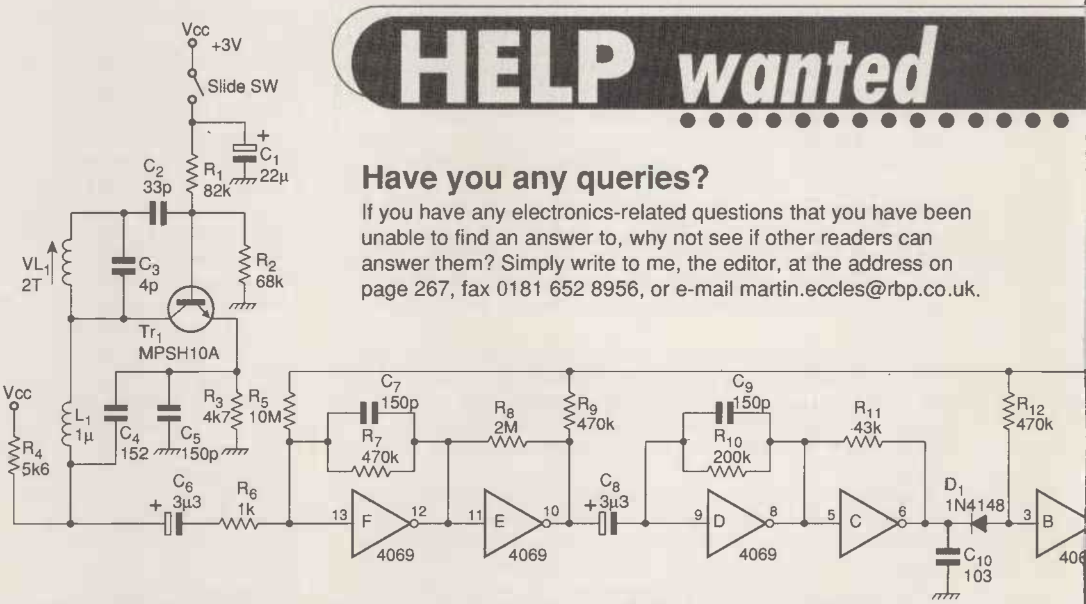
Nor is Caller ID a particularly useful complement to an answering machine. I originally subscribed to the service to screen out bogus calls. I now find I cannot do this for fear of missing out on employment

One area where Caller ID would be useful is in deciding whether or not to answer a second call being

HELP wanted

Have you any queries?

If you have any electronics-related questions that you have been unable to find an answer to, why not see if other readers can answer them? Simply write to me, the editor, at the address on page 267, fax 0181 652 8956, or e-mail martin.eccles@rbp.co.uk.



I would be grateful for your assistance. In the diagrams is a small transmitter and receiver which include encoding and decoding facilities.

Receiver: When the receiver is switched on, once a signal is received, the signal is processed by the components to the left of the solid black vertical line. The output of this processing is the same code sent by the transmitter which enters pin 14 of IC_3. This chip has also been set to the same code as the transmitter. When the correct matching code is received pin 17 goes high to turn on the chime section of the circuit. The section to the right of the solid line is fully understood.

Question 4: How is the signal processed by the receiver in order for the *4069* hex-inverter to work since the frequency of around 340MHz is too high a frequency for the chip to operate?

Question 5: Could it be that the inverters are working as filters? If so how?

Transmitter: The main integrated circuit provides a number of combinations which can be sent by connecting pins 1 to 9 to ground. When power is offered by Call Waiting. However, the number of such a call is not transmitted. From the data in Mr Segaran's article it appears that such an enhancement to the service is probably not possible; in any case BT has informed me that they do not intend to try.

This is a great shame. What is the 'metering and message waiting status' information that BT would like to transmit without alerting the phone user? I have asked BT to explain the 'message waiting' flag on the display of my *CD50* but they cannot be bothered to answer.

I note that the software provided with the *CID-PC1* is for Windows only. For the benefit of pc owners who, like me, have thrown away their copy of Windows, I would like to have DOS tsr software.

I apologise if this letter sounds negative. I have great enthusiasm for the concept of Caller ID and I am saddened by the reality.

Chris Bulman
Bedford

Recalling the facts

The letter from Chris Bulman certainly had a negative spin on Caller ID as a useful service. Although some of the points he makes are relevant, others are factually incorrect.

The 'number unavailable' message is mostly from older exchanges, although calls from subscribers on the catv network will also be delivered as 'unavailable'. However, when the interface between BT and the catv network is upgraded, this information should be available. Regarding mobile telephones, subscribers to the 'Orange' network both receive and transmit caller ID information. Certainly, if other network operators want to offer a competitive service, they too will have to offer this.

Chris is correct in that for 'number withheld' to be set permanently on a line or group of lines, a special request has to be made to BT. As for companies requesting suppression of their number, this is mainly for administrative convenience. Companies that operate DDI (direct dial in) exchanges, have individual numbers for each staff member, but the number delivered is that of the main 'switchboard'. If calls are returned to this number, and not to the individual, then the switchboard will be swamped. I assume that other companies withhold their numbers for other reasons. In practice, this problem is not as extensive as Chris suggests. In our experience, about 70% of all calls to our office have number attached, the remaining being split into number withheld, number unavailable, international and payphone calls.

In the area of Call Waiting, BT is well advanced in trials of such a system and should be introducing it within a matter of months. Its protocol has been defined for some time, and is already operational in some states in the US. Supplier's Information Note 242, as referred to in my article, gives technical details.

Introduction of name on a national basis is much more of a problem. Maintenance of a national database of names – 20 million plus – and the 'instantaneous' look-up of this for every call, presents a big technical and administrative problem that BT seems to be shying away from.

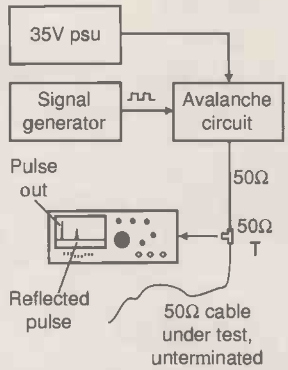
By the way, existing customers can obtain details on the protocol for exchanging Caller-ID data via the serial port.

Seggy Segaran
York

Coaxial cable tester

Design brief in the March 1996 issue discussed working with avalanche transistors and Nick Wheeler's article covered coaxial cable testing. I have combined elements of the two, constructing within a few minutes this avalanche pulse generator for testing and experimenting with coaxial cables.

PW Fry G4SBF
Southampton

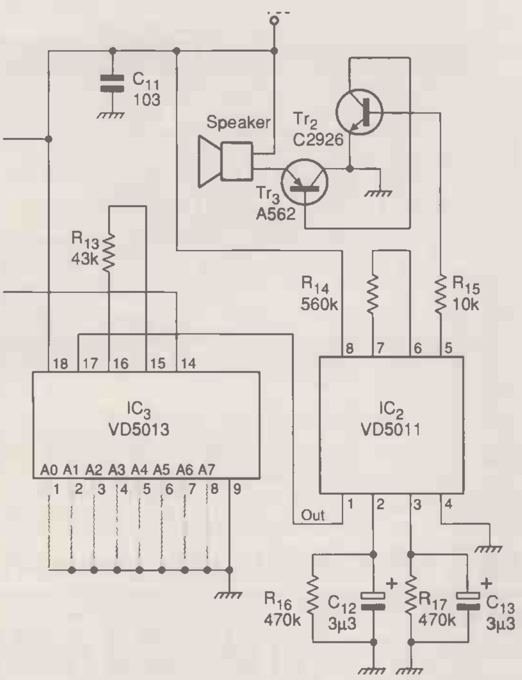


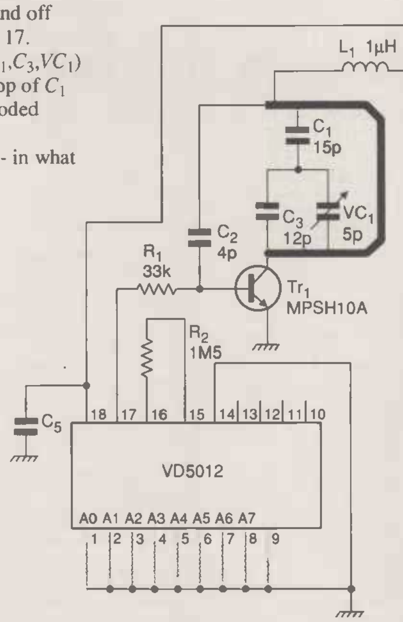
Do you have a vtr?
David Markie has designed a comprehensive remote control interface with pc-based control software for vtrs. It uses the industry standard, or 'Sony', protocol. Write to the editorial offices (Quadrant House address) for more details.

Non-slewing audio power
In this article, from the March issue, the CSA amplifier of Fig. 1 there is a 200Ω resistor between the 50Ω resistor pair junctions. There should be no connection between the junctions. Also, in Fig. 4, the resistor between the diode-junction pairs is 3.3kΩ and the emitter resistors for $Tr_{18,21}$ are 62Ω. Apologies for these.

applied by pressing SW_1 a digital code is sent out of pin 17 of the chip to the base of Q_1. This then turns the transistor on and off according the string of pulses sent out of the chip on pin 17. Doing so connects the oscillator section of the circuit (C_1,C_3,VC_1) to ground. The connector from the emitter of Q_1 to the top of C_1 is the aerial for the transmitter. This then transmits the coded signal, with a range of about 100 feet.

Question 1: Transmission frequency is around 340MHz - in what form is the signal transmitted?





Question 2: Can the value of transmitter frequency be derived from the component values and if so how?

Question 3: Is the above statement correct?

The circuit is sold by Rapid Electronics in kit form, but the company cannot help.

Grahame Collins
Reading College

Schumann Resonance

I wonder if any of your readers could help me with information on Schumann Resonances – particularly in relation to the instrumentation required to detect it – including antenna. The topic is mentioned in *EW*, Research Notes, May 1993.

Ted Crowley
Invotron
Co. Wicklow
Ireland

Would Mr Callegari, who wanted to contact people measuring Schumann Resonances, please let us have his address? – Ed

Headphone bass

Why do small 'personal' earphones give such a good bass response? I do not think they are infinite baffle designs, so why is the low frequency cut-off not higher than it apparently seems to be?

David Gibson
Leeds

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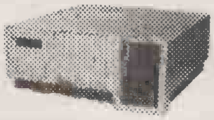

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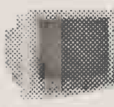

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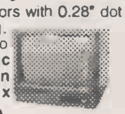

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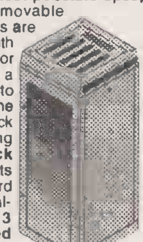

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CIRCLE NO. 115 ON REPLY CARD

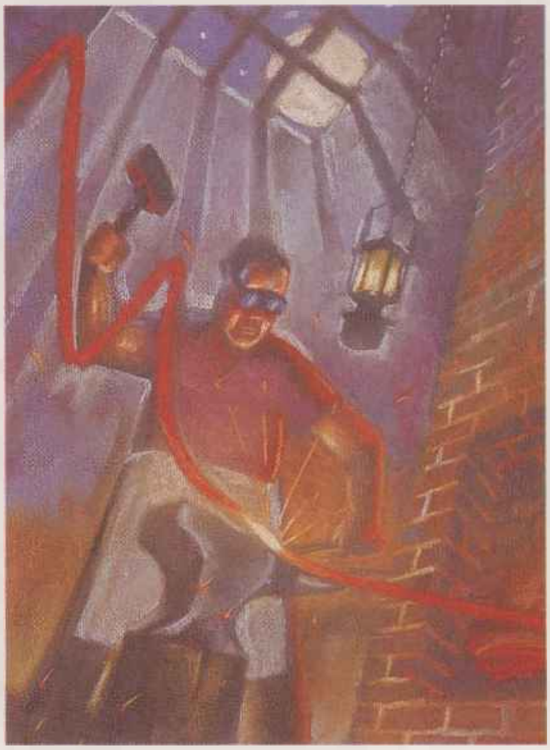
Thermal dynamics in audio power

A Class B amplifier requires thermal compensation to avoid thermal runaway, and because bias setting is critical for the minimisation of crossover distortion, which is generally regarded as the most pernicious of non-linearities. The biasing of a Class B output stage requires the establishment of an accurate voltage drop V_q across emitter resistors R_e of tiny value, by means of hot transistors with varying V_{be} drops. It's surprising it works as well as it does.

This thermal compensation has two main problems, attenuation and delay. Since the thermal sensor is more or less remote from the junction whose gyrations in temperature will hopefully be cancelled out, heat losses and thermal resistances cause the temperature change reaching the sensor to be generally too little and too late for complete compensation.

As in Part 1, all the voltages and errors here are for one half of an output stage, using symmetry to reduce the work involved. These 'half amplifiers' are used throughout this piece for consistency, and the error voltages only doubled to represent reality (a complete output stage) when they are compared against the tolerance bands previously quoted.

In this study, we are faced with errors that vary not only in magnitude, but also in their persistence over time; judgement is required as to whether a prolonged small error is better than a large error which quickly fades away.



In Part 2 of his analysis of thermal dynamics in high performance power amplifiers, Douglas Self discusses the importance of temperature sensor location.

The absolute error criterion

The same issue faces most servomechanisms, and I borrow from Control Theory the concept of an 'Error Criterion' which combines magnitude and time into one number[1,2]. The most popular criterion is the Integrated Absolute Error (IAE), which is computed by integrating the absolute value of the error over a specified period after giving the system a suitably provocative stimulus; the absolute value prevents positive and negative errors cancelling over time. Another common criterion is the Integrated Square Error (ISE) which solves the polarity problem by squaring the error before integration – this also penalises large errors much more than small ones. It is not immediately obvious which of these is most applicable to bias control and the psychoacoustics of crossover distortion that changes with time, so I have chosen the popular IAE.

One difficulty is that the IAE error criterion for bias voltage tends to accumulate over time, due to the integration process, so any constant bias error quickly comes to dominate the IAE result. In this case, the IAE is little more than a counter intuitive way of stating the constant error, and must be quoted over a specified integration time to mean anything at all. This is why the IAE concept was not introduced in the first part of this article.

Much more useful results are obtained when the IAE is applied to a situation where the error decays to a very small value after the initial transient, and stays there. This can sometimes be arranged in amplifiers, as I hope to show. In an ideal system where the error decayed to zero without overshoot, the IAE would asymptote to a constant value after the initial transient. In real life, residual errors make the IAE vary slightly with time, so for consistency all the IAE values given here are for 30s after the step input.

The emitter-follower stage

In the first part of this article, it was shown that the basic emitter-follower (ef) stage with the sensor on the main heatsink has significant thermal attenuation error and therefore under compensates temperature changes. The V_q error is +44mV, the positive sign showing it is too high. If the sensor is on the TO3 can top it over compensates instead, V_q error equals −30mV.

If an intermediate configuration is contrived by putting a layer of controlled thermal resistance 80°C/W, between the TO3 top and the sensor, then the 50s timescale component of the error can be reduced to near zero. This is the top error trace in bottom half of **Fig. 1**. The lower trace shows the wholly misleading result if sensor heat losses are neglected in this configuration.

Despite this medium term accuracy, if the heat input stimulus remains constant over the very long term (several kilo-seconds) there still remains a very slow drift towards over compensation due to the slow heating of the main heatsink, **Fig. 2**. This extra complication over very long periods was glossed over in Part 1 due to sheer lack of space.

This long term drift is a result of the large thermal inertia of the main heatsink and since it takes 1500s (25 minutes) to go from zero to −32mV is of doubtful relevance to the timescales of music and signal level changes. On doubling to −64mV, it remains within the ef V_q tolerance of ±100mV. On the shorter 50s timescale, the half amplifier error remains within a ±1mV window from 5s to 60s after the step input.

For the ef stage, a very long term drift component will always exist so long as the output device junction temperature is kept down by means of a main heatsink that is essentially a weighty chunk of finned metal.

The ef system stimulus is a 20W step as before, being roughly worst case for a 100W amplifier. Using the 80°C/W thermal semi-insulator described above gives the upper error trace in **Fig. 3**, and an IAE of 254mV/s after 30s. This is relatively large because of the extra time delay caused by the combination of an increased R_{22} with the unchanged sensor thermal capacity C_6. Once more, this figure is for a half amplifier, as are all IAEs in this article.

Up to now I have assumed that the temperature coefficient of a V_{be}-multiplier bias generator is rigidly fixed at −2mV/°C times the V_{be}-multiplication factor, which is about 4.5× for ef and 2× for cfp. The above figures are for both halves of the output stage, so the half amplifier value for ef is −4.5mV/°C, and for cfp −2mV/°C.

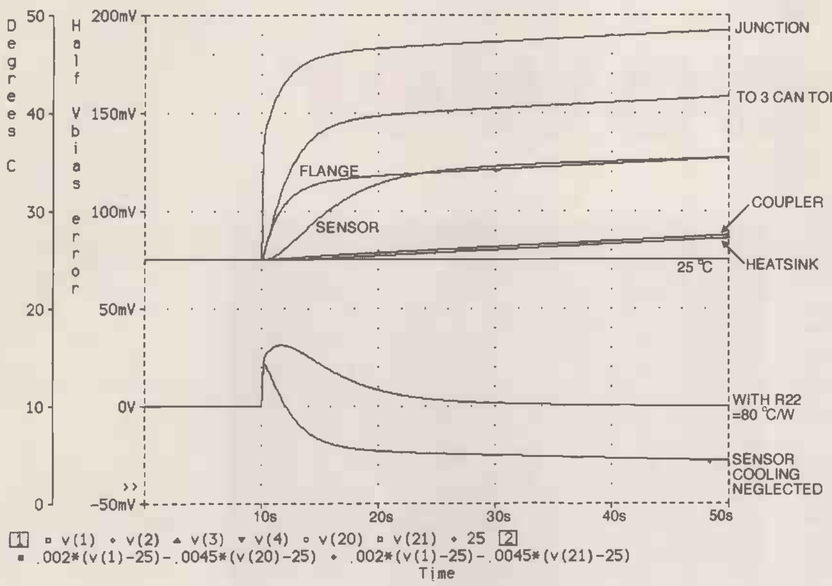


Fig. 1. EF behaviour with semi-insulating pad under sensor on TO3 can top. The sensor in the upper temperature plot rises more slowly than the flange, but much faster than the main heatsink or coupler. In lower Vq-error section, upper trace is for a 80°C/W thermal resistance under the sensor, giving near zero error. Bottom trace shows serious effect of ignoring sensor cooling in TO3-top version.

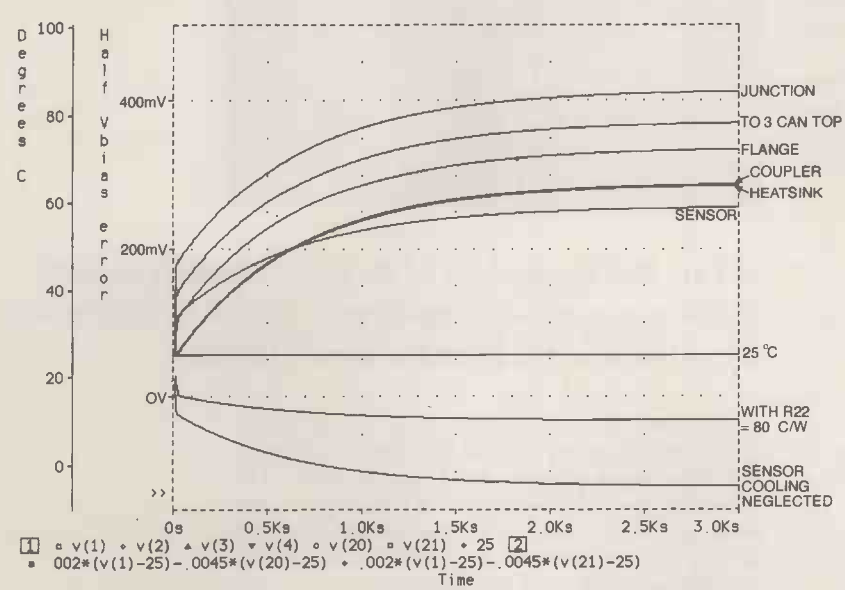


Fig. 2. Over a long timescale, the lower plot shows that the Vq error, although almost zero in Fig. 1, slowly drifts into over compensation as the heatsink temperature (upper plot) reaches asymptote.

Speeding the response

Staying with ef, if we boldly assume that the V_{bias} generator can have its thermal coefficient varied at will, the insulator and its aggravated time lag can be eliminated. If the 80°C/W thermal pad is replaced with standard material, between the sensor and the TO3 top, the optimal V_{bias} coefficient for minimum error over the first 40s proves to be −2.8mV/°C, which is notably less than −4.5. The resulting 30s IAE is 102mV/s, more than a two times improvement. See the lower trace in Fig. 3, for comparison with the semi-insulator method described above. In view of the fixed time constants, dependant upon a certain weight of metal being required for heat dissipation, it appears that the only way this performance could be significantly improved upon might be to introduce a new kind of output transistor with an integral diode that would sense the actual junction temperature, being built into the main transistor junction structure. Although it would be of immense help to amplifier makers, no one seems to be keen to do this.

From here on I am going to assume that a variable temperature coefficient (tempco) bias generator can be made when required. The details of how to do it must wait for a later article. It should be an extremely useful device, as thermal attenuation can then be countered by increasing the 'thermal gain'. It does not however help with the problem of thermal delay.

In the second ef example above the desired tempco is –2.8mV/°C, while an ef output stage plus V_{be}-multiplier has an actual tempco of –4.5mV/°C. In this case we need a bias generator that has a *smaller* tempco than the standard circuit. The conventional ef with its temp sensor on the relatively cool main heatsink would require a *larger* tempco than standard.

A potential complication is that amplifiers should also be reasonably immune to changes in ambient temperature, quite apart from changes due to dissipation in the power devices. The standard tempco gives a close approach to this automatically, as the V_{be}-multiplication factor is naturally almost the same as the number of junctions being biased. However, this will no longer be true if the tempco is significantly different from standard, so it is necessary to think about a bias generator that has one tempco for power device temperature changes and another for ambient changes. This sounds rather daunting but actually proved fairly simple.

Complementary feedback-pair output

As revealed in Part 1, the complementary feedback pair (cfp) output stage has a much smaller bias tolerance of ±10mV for a whole amplifier, and surprisingly long time constants. A standard cfp stage therefore has larger relative errors than the conventional emitter follower (ef) stage with thermal sensor on the main heatsink. This is the opposite of conventional wisdom. Moving the sensor to the top of the TO3 can was shown to improve the ef performance markedly, so we shall attempt an analogous improvement with driver compensation.

The standard cfp thermal compensation arrangements have the sensor mounted on the driver heatsink, so that it senses the heatsink temperature rather than that of the driver itself. See **Fig. 4a** for mechanical arrangement, and **Fig. 5** for thermal model. As in the ef, this gives a constant long term error due to the sustained temperature difference between the driver junction and heatsink mass. See the upper traces in **Fig. 7**, plotted for different bias tempcos. The cfp stimulus is a 0.5W step, as before. This constant error cannot be properly dealt with by choosing a tempco that gives a bias error passing through zero in the first fifty

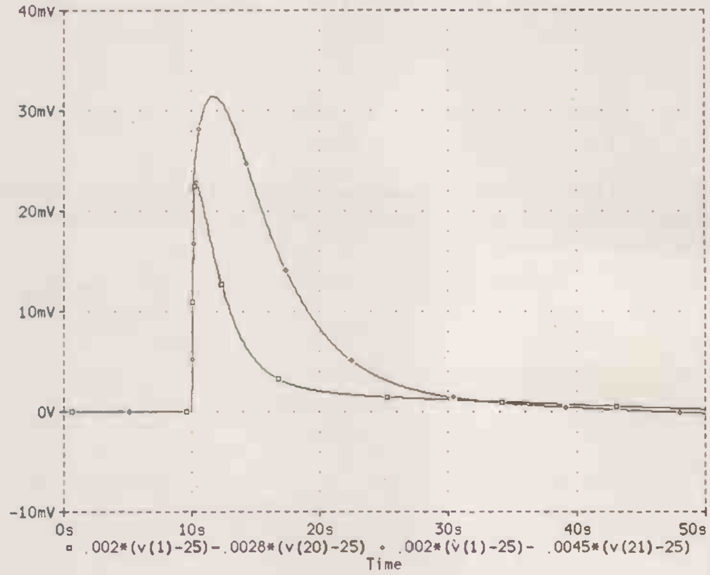


Fig. 3. The transient error for the semi-insulating pad and the low tempco version. The latter responds much faster, with a lower peak error, and gives less than half the Integrated Absolute Error (IAE).

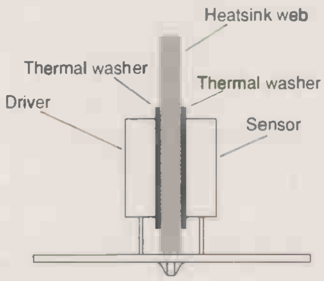
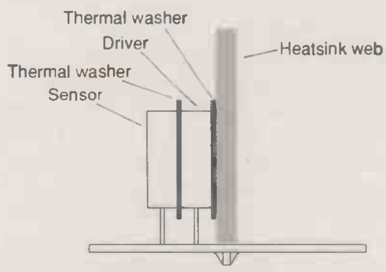
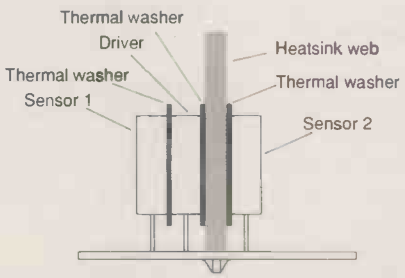


Fig. 4. a) The sensor transistor on the driver heatsink.



b) An improved version, with the sensor mounted on top of the driver itself, is more accurate.



c) Using two sensors to construct a junction estimator.

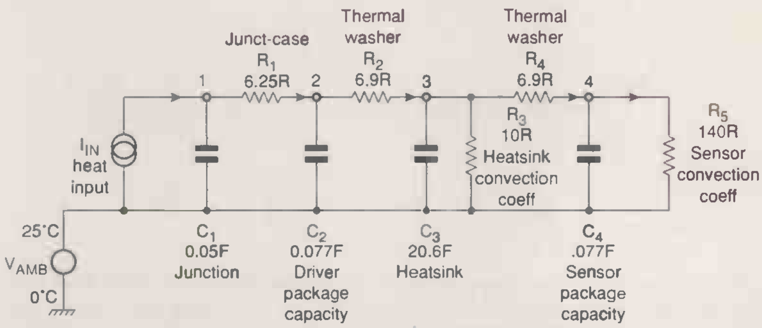


Fig. 5. Thermal circuit of normal CFP sensor mounting on heatsink. R_3 is the convective cooling of the heatsink, while R_5 models heat losses from the sensor body itself.

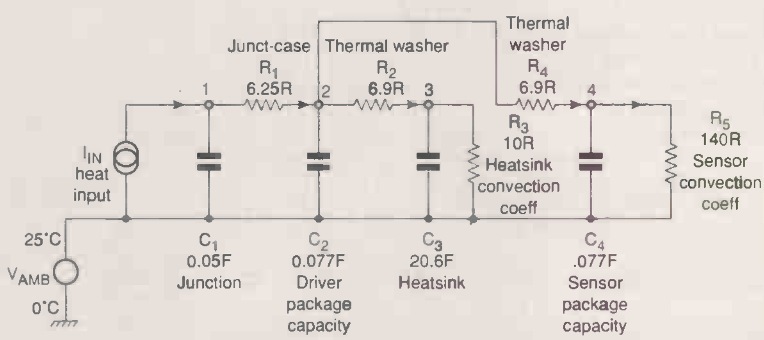


Fig. 6. Thermal circuit of driver-back mounting of sensor. The large heatsink time constant R_2-C_2 is no longer in the direct thermal path to the sensor, so the compensation is faster and more accurate.

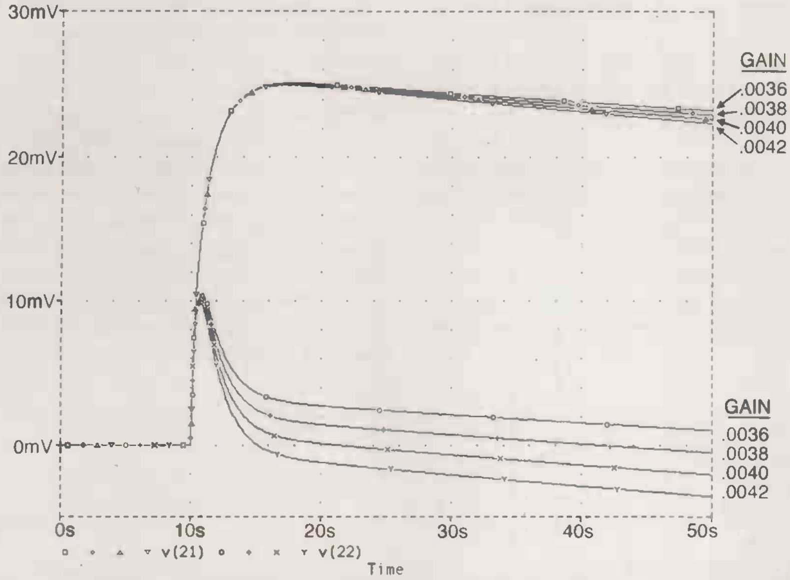


Fig. 7. The Vq errors for normal and improved sensor mounting, with various tempcos. The improved method can have its tempco adjusted to give near zero error over this timescale. Not so for the usual method.

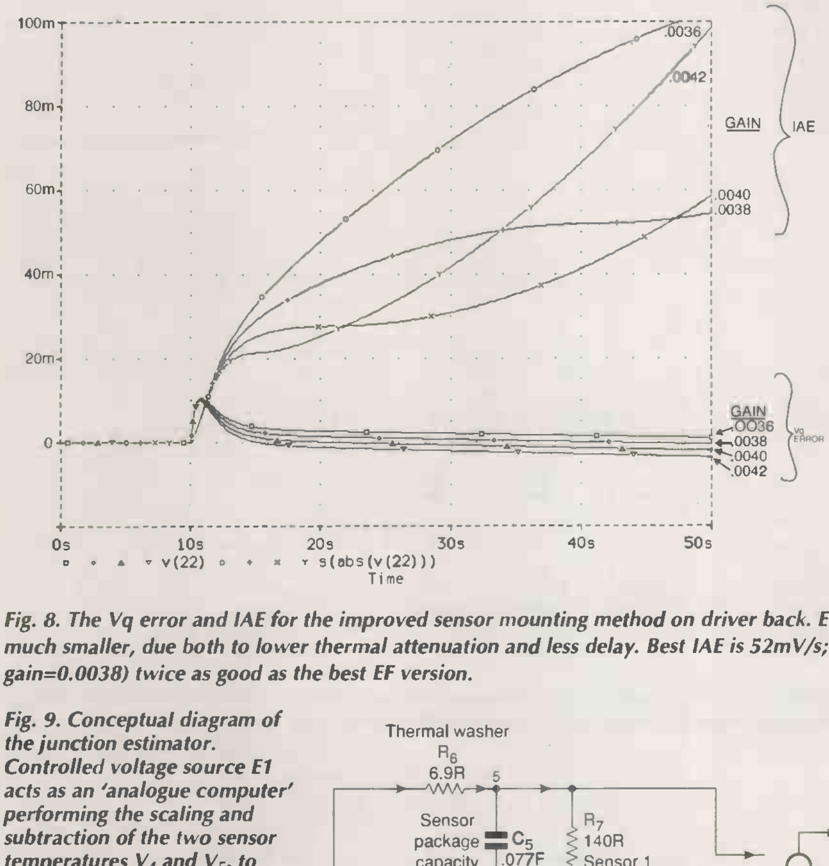
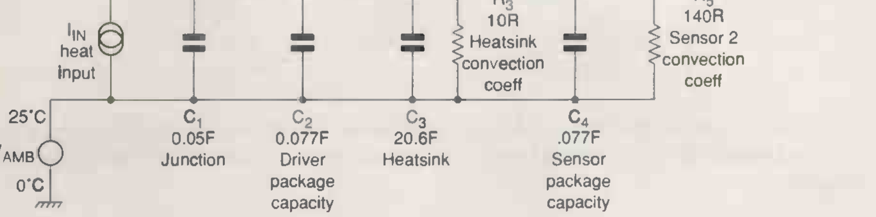


Fig. 8. The Vq error and IAE for the improved sensor mounting method on driver back. Error is much smaller, due both to lower thermal attenuation and less delay. Best IAE is 52mV/s; (with gain=0.0038) twice as good as the best EF version.

Fig. 9. Conceptual diagram of the junction estimator. Controlled voltage source E1 acts as an 'analogue computer' performing the scaling and subtraction of the two sensor temperatures V_4 and V_5, to derive the bias voltage.



seconds, as was done for the ef case with a TO3-top sensor, as the heatsink thermal inertia causes it to pass through zero very quickly and head rapidly South in the direction of ever increasing negative error. This is because it has allowed for thermal attenuation but has not decreased thermal delay. It is therefore pointless to compute an IAE for this configuration.

A better sensor position

By analogy with the TO3 and TO3P transistor packages examined earlier, it will be found that flat driver packages such as *TO-225AA* on a heatsink get hotter faster on their exposed plastic face than any other accessible point. It looks as if a faster response will result from putting the sensor on top of the driver rather than on the other side of the sink as usual. With the Redpoint *SW38-1* heatsink this is fairly easy as the spring clips used to secure one plastic package will hold a stack of two *TO-225AA*'s with only a little physical persuasion. A standard thermal pad is used between the top of the driver and the metal face of the sensor, giving the sandwich shown in **Fig. 4b**. The thermal model is **Fig. 6**. This scheme greatly reduces both thermal attenuation and thermal delay, (lower traces in Fig. 7) giving an error that falls within a ±1mV window after about 15.5s, when the tempco is set to –3.8mV/°C. The IAE computes to 52mV, as shown in **Fig. 8**, which demonstrates how the IAE criterion tends to grow without limit unless the error subsides to zero. This value is a distinct improvement on the 112mV IAE which is the best that could be got from the ef output.

The effective delay is much less because the long heatsink time constant is now partly decoupled from the bias compensation system.

A junction estimator

It appears that we have reached the limit in what can be done, as it is hard to get one transistor closer to another than they are in Fig. 4b. It is however possible to get better performance, not by moving the sensor position, but by using more of the available information to make a better estimate of the true driver junction temperature. Such 'estimator' subsystems are widely used in servo control systems where some vital variable is inaccessible, or only knowable after such a time delay as to render the data useless[3]. It is often almost as good to have a 'model system', usually just an abstract set of gains and time constants, which will give an estimate of what the current value of the unknown variable must be, or ought to be.

The situation here is similar, and the first approach makes a better guess at the junction temperature V(1) by using the known temperature drop between the package and the heatsink. The inherent assumption is made that the driver package is isothermal, as it is modelled by one temperature value V(2).

If two sensors are used, one placed on the heatsink as usual and the other on top of the driver package, as described above **Fig. 4c**, then things get interesting. Looking at Fig. 6, it can be seen that the difference between the driver junction temperature and the heatsink is due to R_1 and R_2. The value of R_1 is known, but not the heat flow through it. Neglecting small incidental losses, the temperature drop through R_1 is proportional to the drop through R_2. Since C_2 is much smaller than C_3, this should remain reasonably true even if there are large thermal transients. Thus, measuring the difference between V(2) and V(3) gives a reasonable estimate of the difference between V(1) and V(2). When this difference is added to the known V(2), we get a rather good estimation of the inaccessible V(1). This system is shown conceptually in **Fig. 9**, which gives only the basic method of operation. The details of the real circuitry must wait until we have decided exactly what we want it to do.

We can only measure V(2) and V(3) by applying thermal sensors to them, as in Fig. 4c, so we actually have as data the sensor temperatures V(4) and V(5). These are converted to bias voltage, scaled and subtracted, thus estimating the temperature drop across R_1 this is added to V(5) to give the estimate of V(1). The computation is done by Voltage-Controlled-Voltage-Source E1, which in PSpice can have any equation assigned to define its behaviour. Such definable VCVS's are very handy as little 'analogue computers' that do calculations as part of the simulation model. The V(1) result is then multiplied by a scaling factor called estgain which is incorporated into the defining equation for E1, and is adjusted to give the minimum error. Note the variable tempco bias approach is used to allow for the difference in resistance between R_1 and R_2.

The results are shown in **Fig. 10**, where an estgain of 1.10 gives the minimum IAE of 25mV/s. The transient error falls within a ±1mV window after about 5s. This is a major improvement, at what promises to be little cost.

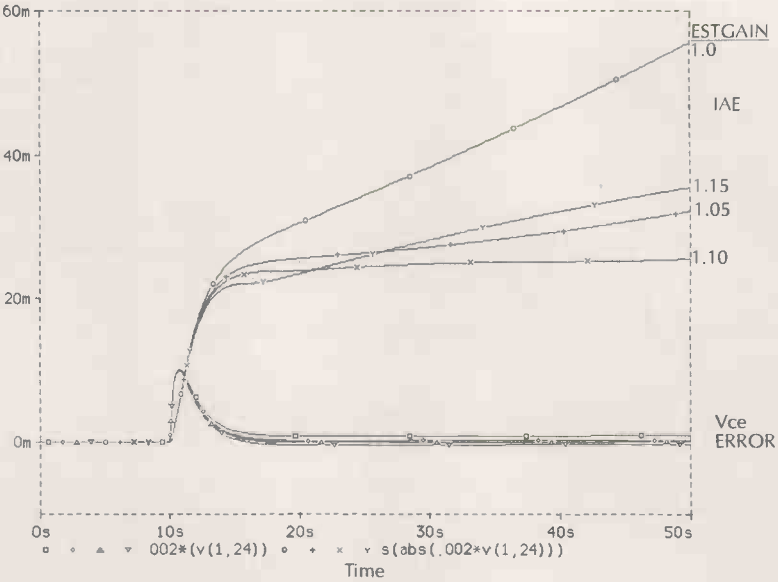


Fig. 10. Simulation results for the junction estimator, for various values of estgain. The optimal IAE is halved to 25mV/s; compare with Fig. 8.

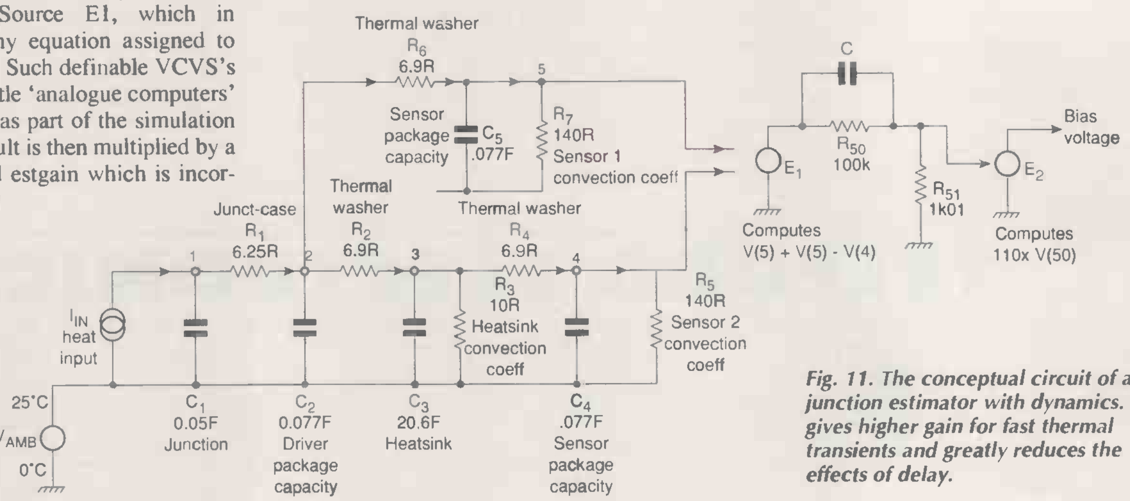


Fig. 11. The conceptual circuit of a junction estimator with dynamics. C gives higher gain for fast thermal transients and greatly reduces the effects of delay.

A junction estimator with dynamics

The remaining problem with the junction estimator scheme is still its relatively slow initial response. Nothing can happen before heat flows through R_6 into C_5, in Fig. 9. It will take even longer for C_4 to respond, due to the inertia of C_3, so we must find a way to speed up the dynamics of the junction estimator.

The first obvious possibility is the addition of phase advance to the forward bias com-

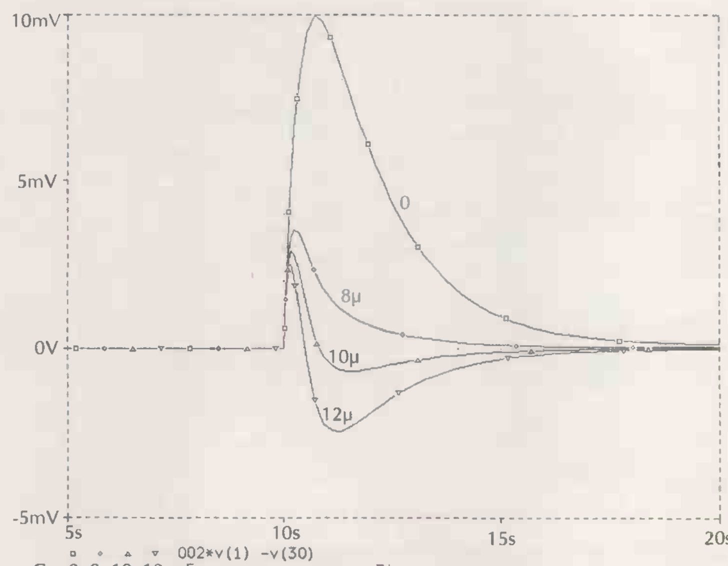


Fig. 12. The initial transient errors for different values of C. Too high a value causes undershoot.

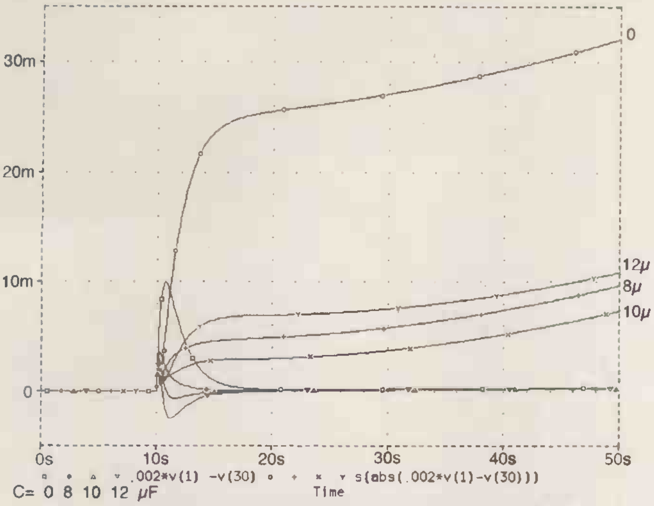


Fig. 13. The IAE for different values of C. 10μF is clearly best for minimum integrated error, (IAE=7.3mV/s) but even a rough value is a great improvement.

pensation path. This effectively gives a high gain initially, to get things moving, which decays back over a carefully set time to the original gain value that gave near zero error over the 50s timescale. The conceptual circuit in **Fig. 11** shows the phase advance 'circuitry' added to the compensation path. The signal is attenuated 100 times by R_{50} and R_{51}, and then scaled back up by VCVS E2, which is defined to give a gain of 110 times, incorporating an estgain of 1.10 times. C causes fast changes to bypass the attenuation, and its value in conjunction with R_{50} and R_{51} sets the degree of phase advance or lead. The slow behaviour of the circuit is thus unchanged, but transients pass through C and are greatly amplified by comparison with steady state signals.

The result on the initial error transient of varying C around its optimal value can be seen in the expanded view of **Fig. 12**. The initial rise in V_q error is pulled down to less than a third of its value if C is made 10μF. With a lower C value the initial peak is still larger than it need be, while a higher value introduces some serious undershoot that causes the IAE to rise again, as seen in the upper traces in **Fig. 13**. The big difference between no phase advance, and a situation where it is even approximately correct, is very clear.

With C set to 10μF, the transient error falls within a ±1mV window after only 0.6s, which is more than twenty times faster than the first improved cfp version, (sensor put on driver) and gives a nicely reduced IAE of 7.3mV/s at 50s. The real life circuitry to do this has not been designed in detail, but presents no obvious difficulties. The result should be the most accurately bias compensated Class B amplifier ever conceived.

In summary

It is, I hope, clear that most of this work is purely theoretical and would be much the better for confirmation by practical tests. This would be a mountain of work and I have no intention of undertaking it.

Hopefully it is equally clear that it is no longer necessary to accept 'V_{be}-multiplier on the heatsink' as the only option for the crucial task of V_{bias} compensation. The alternatives presented promise greatly superior compensation accuracy.

The third part of this series will deal with variable tempco bias generators. ■

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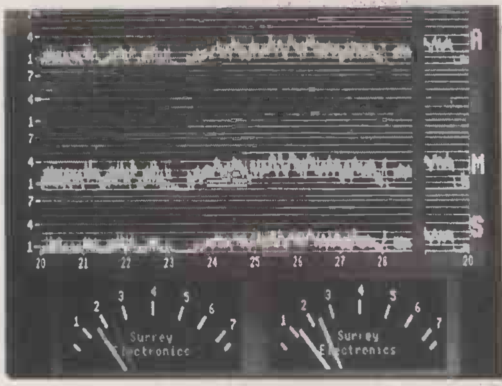

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Designing for spectrum analysis

Felice Labbrozzi outlines modules of his high-performance, yet economical, spectrum analyser.

A typical spectrum analyser, one not based on fast Fourier transforms, is essentially a superheterodyne receiver. Within this receiver the local oscillator, a vco, is swept using a sawtooth signal. The oscillator starting frequency equals the intermediate frequency.

With this technique, the received frequency theoretically starts from zero, or dc. In practice, the lower limit is affected by the IF filter response and the input dynamic range. The higher frequency is related to the first IF value.

Design criteria

In order to develop a useful set of specifications for the spectrum analyser, I examined ten commercial spectrum analysers. The specifications I chose are shown in the panel.

Measurements displayed on a spectrum analyser's vertical axis usually need to be logarithmic. As a result, the input voltage is passed through a logarithmic amplifier.

As with any heterodyne receiver the ability to select the signals received is determined by the intermediate-frequency filter. When tuning rapidly to different signals with a bandwidth near to or lower than the band of the detected signals, there are no simple effects. This is because the time needed by a signal to pass through a filter is inversely proportional to its bandwidth.

As a result, to analyse signals with different characteristics, it is necessary to change three parameters. These are,

- bandwidth – selectivity of the intermediate-frequency filters
- span – the frequency range of the measurement in question
- sweep time – the time needed to analyse the same frequency range.

Spectrum analyser design goals

- Frequency range dc to 1GHz
- Dynamic display of more than 80dB with linearity of around ±1dB
- Input amplitude range +30, –120dBm minimum
- Frequency accuracy dependent on only one reference oscillator
- Resolution lower than 1kHz
- Ability to print reports, graphs and comparisons
- Capability for storing measurements on dos disks

Analyser system elements

To accommodate a range of signals from very large to those close to the thermal noise level, a very sensitive front end circuit is needed, preceded by an attenuator. This attenuator must have precise and repeatable characteristics over the whole frequency and amplitude range of the instrument. For this reason I have made it a separate module, **Fig. 1**.

Input frequencies over a gigahertz could be converted by harmonics from the vco. Displaying all the vco harmonic responses at the same time is likely to cause confusion. In order to separate the spurious responses from the required signals it is better to use a low-pass input filter. This will attenuate those signals higher than 1GHz. If it is necessary to extend the input frequency band, the low pass filter can be replaced by band pass preselectors of 1GHz each. The rf attenuator and the first mixer should be adequate enough to cope with this frequency range if the required amplitude response is to be achieved.

All rf circuits are mounted on one pcb and all control lines are dc. When this module receives input

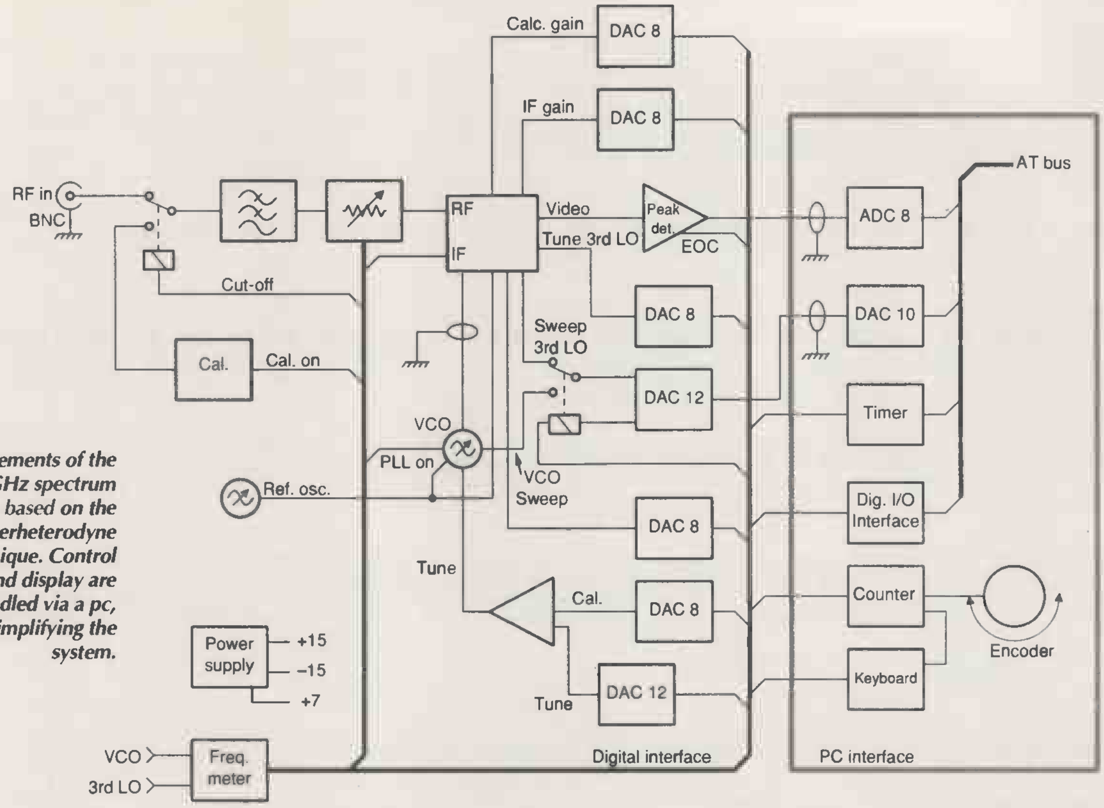


Fig. 1. Elements of the 1GHz spectrum analyser, based on the superheterodyne technique. Control and display are handled via a pc, greatly simplifying the system.

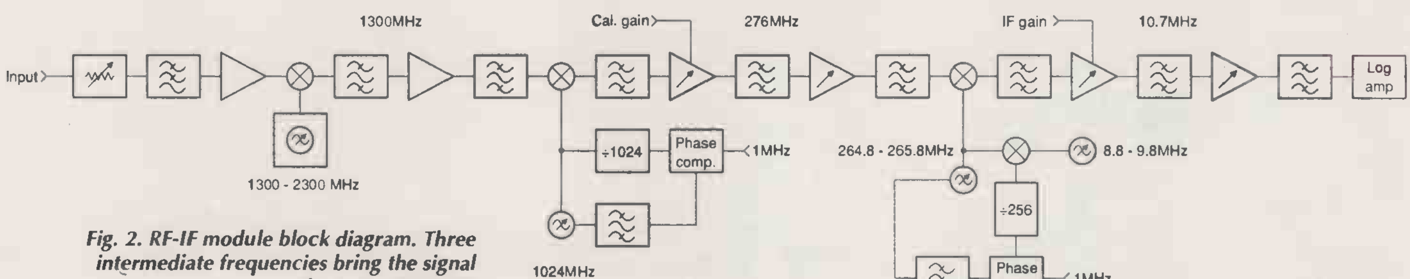


Fig. 2. RF-IF module block diagram. Three intermediate frequencies bring the signal down to 10.7MHz.

signals together with those from the vco, it sends the resulting signal to the digital interface and then to the pc interface. This signal is converted to digital form for display and/or computation.

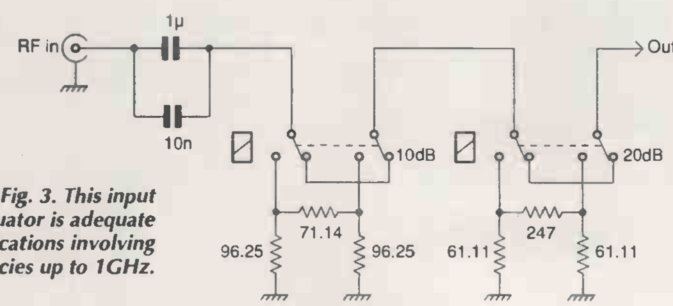


Fig. 3. This input attenuator is adequate for applications involving frequencies up to 1GHz.

RF and intermediate-frequency

Measurement receiver **Figure 2** uses three frequency conversions to bring the input signal to 10.7MHz. This frequency is processed by quartz filters with variable band width and then applied to a logarithmic amplifier such as a *TDA1576*. After the filters, a low cost logarithmic amplifier such as *TDA1576*s works well.

When two signals are mixed, the product of the mixed signal has all the characteristics of the original signal, together with those of the local oscillator. To avoid additional noise as each local oscillator increases the original signal, all local oscillators are controlled via phase lock loops. In this way, the local oscillators can be locked to just one stable and low noise oscillator reference derived from the internal frequency reference.

An exception to this is the third local oscillator, which can be continuously tuned over 1MHz when the first vco is phase locked. Here, phase noise near the carrier remains low enough to be ignored.

The vco has to be tuneable over a very large band – typically 1.3 to 2.3GHz. Because of this, the stability and noise performance required to detect signals hundreds of hertz apart cannot be guaranteed.

All rf amplifiers operating under 1GHz are dual-gates mosfets – *BF 961*s, or *40673*s for 10.7MHz. These are straightforwardly configured, with gain being controlled via the second gate. The input amplifier and 1.3GHz amplifier comprise inexpensive minicircuits *MAR 6*s and *BFR91*s.

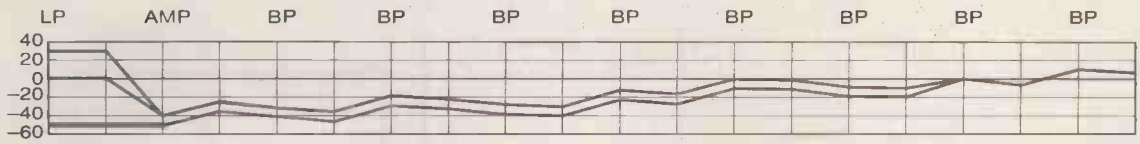
System gain is software controlled. Software also compensates for small ripples due to components or their coupling. This makes selection of the first mixer less critical and cheaper.

An auto calibration routine imposes a flat response to the whole system when a signal derived from a harmonic generator is connected to the input.

RF attenuation

If you are not interested in extending the frequency range over 1GHz, you can make the rf attenuator following **Fig. 3**.

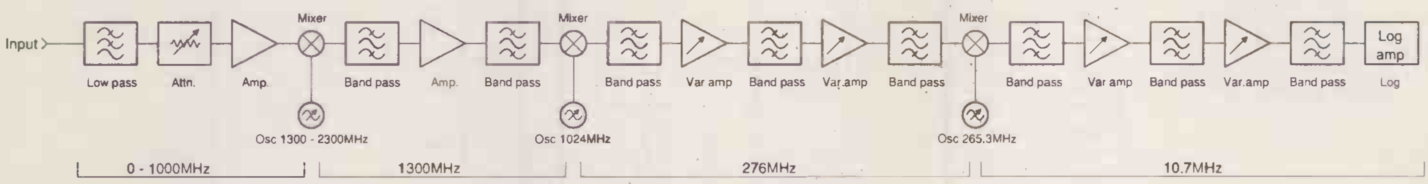
To form a 40dB attenuator, it is better to connect two 20dB sections together. If we use



	LP	Att.	Amp	Mix 1	BP	Amp	BP	Mix 2	BP	Amp	BP	Var amp	BP	Mix 3	BP	Var amp	BP	Amp	BP
Min. noise	−0,5	− 0,5	16	−7	−2	15	−3	−7	−1	17	−4	17	−1	−7	−1	19	−6	16	−3
Typ. gain	−0,5	−40,5	16	−7	−2	15	−3	−7	−1	17	−4	17	−1	−7	−1	9	−6	16	−3
Max. gain	−0,5	−70,5	16	−7	−2	15	−3	−7	−1	7	−4	17	−1	−7	−1	19	−6	16	−3

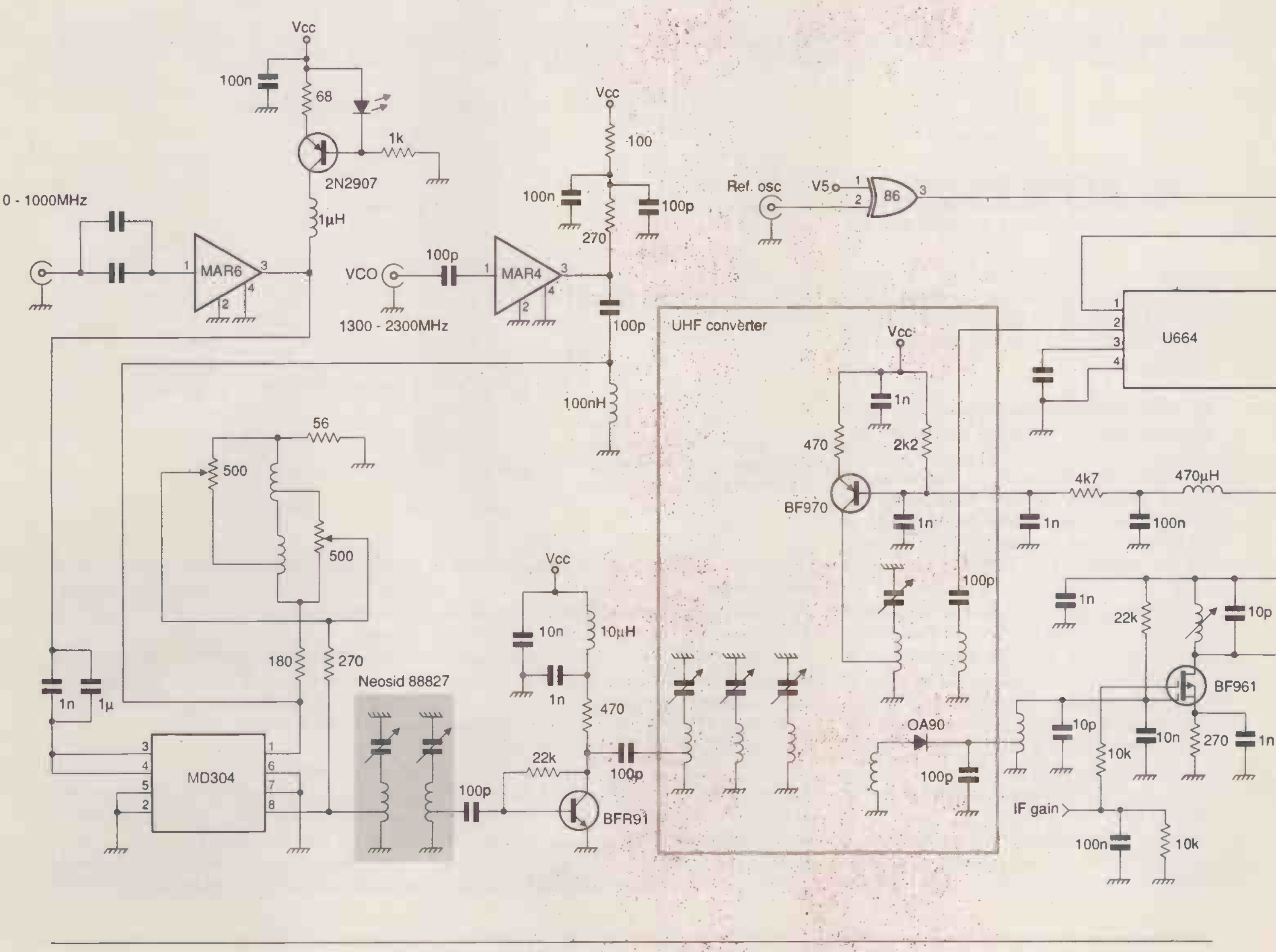
dBm levels	LP	Att.	Amp	Mix 1	BP	Amp	BP	Mix 2	BP	Amp	BP	Var. Amp	BP	Mix 3	BP	Var. amp	BP	Amp	BP	Log amp
Max.sens.	−50	−50,5	−51	−35	−42	−44	−29	−32	−39	−40	−23	−27	−10	−11	−18	−19	0	−6	10	7
Typ.	0	−0,5	−41	−25	−32	−34	−19	−22	−29	−30	−13	−17	0	−1	−8	−9	0	−6	10	7
Max. level	30	29,5	−41	−25	−32	−34	−19	−22	−29	−30	−23	−27	−10	−11	−18	−19	0	−6	10	7

Fig. 4. Performance figures for various stages of the spectrum analyser signal processing chain.



$F=F_1+(F_1-2)/G_1+(F_3-1)/G_1G_2=2.91$ (see text), and $NF=10\log F=4.65$dB

Fig. 5. Front end synthesis. Theoretically, given a noise figure, NF, of 4.65, a signal just 3dB above noise can be detected.



only one pi network attenuator, stray capacitances limit the frequency response to under 1GHz. Selecting or parallelling standard carbon resistors a 70dB attenuator can be made, increasing the dynamic range of the system. It is necessary to repeat the 20dB section three times using low capacitance reed relays. Excitation coils of the two dual-ganged relays are connected together, as shown.

You must cut the connections as short as possible. The best method is to compute a 50Ω strip line, and insert the relays in the middle of it cutting the strip between the relay's pins. Relays should have an appropriate pin-out; I used *FEME ZFH 002 12* types.

Input capacitors are unpolarised tantalum and ceramic types. If you cannot use surface-mount components, cut the resistor wires down to an absolute minimum and solder the remaining tag directly onto the relay pins.

To compensate for stray capacitances, two short teflon insulating wires can be connected in parallel with the series resistors. Winding the wires together acts as a small capacitor, helping to maintain a flat frequency response.

The following circuit descriptions are not unique solutions. I have tried several different types of circuit, each with good results. However, if you decide to change the schematics, ensure that the local oscillator rf power is higher than +7dBm. This guarantees acceptable values, imposed in the system design, for losses in the balanced mixers. If the oscillators have a high harmonic content, it is better not to increase the rf power more than 3dB otherwise you could have difficulties reducing spurious responses.

The second conversion, 1300 to 276MHz, was made in a separate silvered-brass box measuring 10 by 50 by 85mm. Inside this box I made resonant coupled circuits using small 6mm brass tubes, teflon standard insulators, small plastic tubes and 3M bolts.

The second mixer uses an *OA90* or *AA119* germanium diode but I also tested *HP5082* series schottky diodes with good dynamic range results.

Designing the rf system

After selecting the conversion frequencies so that the harmonics or mixing products do not block the intermediate-frequency or generate strong spurious frequencies, it is possible to design the amplifier and establish the noise figure of the receiver system.

From the local oscillator and intermediate frequencies you can compute the intermediate -frequency filters so that the attenuation of the images frequencies and the 6/60dB frequency band ratio reaches the desired level. Divide insertion losses so that no filter exceeds 10dB. With a spread sheet such as *Excel* you can assign the gain needed for each amplifier so that you arrive at the input level needed for the log amplifier input, **Fig. 4**.

You can consider the noise figure of a passive mixer as being roughly the same value as its loss. The passive stages can be grouped together in series, making it possible to draw an equivalent block diagram.

Remember that the noise figure of a circuit with a loss of *A* decibels, connected to the input of an amplifier with noise figure *NF* decibels, is *A+NF* decibels. A cascade of two amplifiers with N_1, G_1 and N_2, G_2 will show looking from the input,

$$F=F_1+(F_2-1)/G_1$$

or in decibels, a noise figure,

$$NF=10\times\log F.$$

Now you can draw an equivalent block diagram with three or four stages in cascade. Within this diagram, you can integrate the losses before each amplifier.

To find the system's noise figure, apply the formula to these equivalent amplifiers for two cascade modules, starting from the last amplifier. Make sure that formulas consider decimals, ie do not mix it with decibels.

The lowest detectable signal depends on the noise present, which is proportional to the band width of the testing system. The minimum noise that cannot be cut, with a bandwidth *B* of 1kHz, has a power,

$$N=10\log\frac{KTB}{10^{-3}}=-144\text{dBm}$$

where K is the Boltzmann's constant, 1.38×10^{-23}, and T= 293K, ie room temperature.

Thus theoretically, given a noise figure, *NF*, of 4.65, as per **Fig. 5**, a signal just 3dB above noise can be detected. This corresponds to a level of,

$$-144+4.65+3=-136.65\text{dBm}.$$

When the vco generates 1300MHz it is important that the first amplifier, which has to operate on the lowest amplitude signals, does not saturate. To decrease the signal passing through the mixer, a double balanced type is insufficient.

I have made a phase network to produce a 1300MHz signal with opposite phase, and the same amplitude as the mixer output. The res-

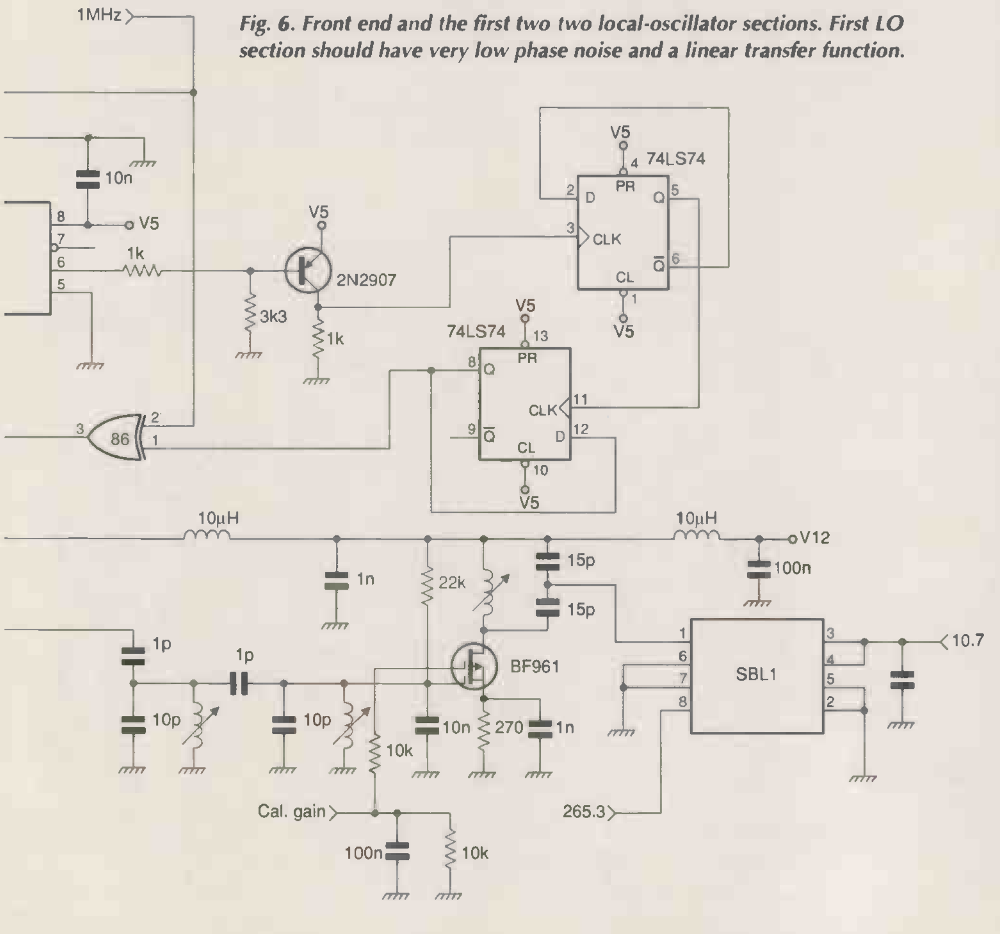


Fig. 6. Front end and the first two two local-oscillator sections. First LO section should have very low phase noise and a linear transfer function.

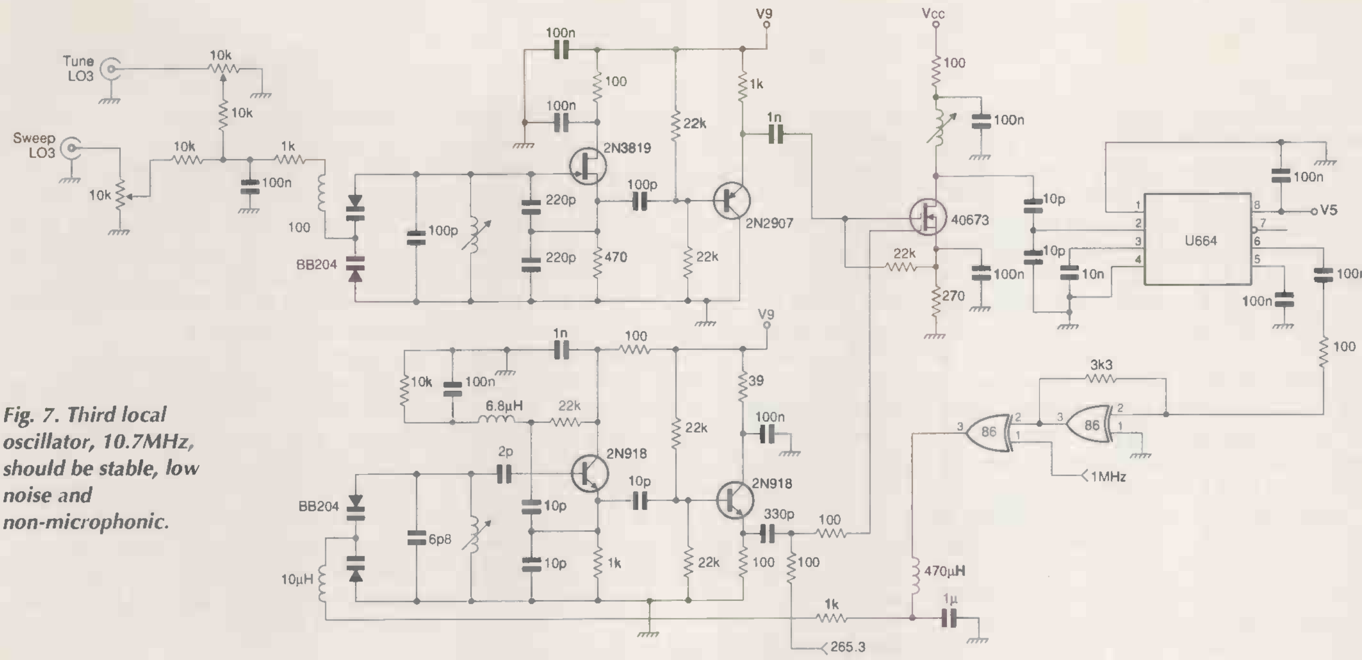


Fig. 7. Third local oscillator, 10.7MHz, should be stable, low noise and non-microphonic.

onant lines, a quarter wavelength, shown in **Fig. 6**, were made with teflon *RG174* coaxial cable and the trimmers are miniature carbon types, as are the resistors.

Third local oscillator

The third local oscillator, Fig. 7, is simple, especially if it is phase locked loop with a very high comparator frequency.

The high comparator frequency guarantees short lock time and spurious signals are far from the carrier minimum of 1MHz. As a result, they are outside the range of the intermediate-frequency filters.

With a direct synthesis phase-locked loop, it is possible to further decrease phase noise and increase stability. This circuit does not limit the noise characteristics of the spectrum analyser provided that you take care with the 9MHz voltage-controlled oscillator.

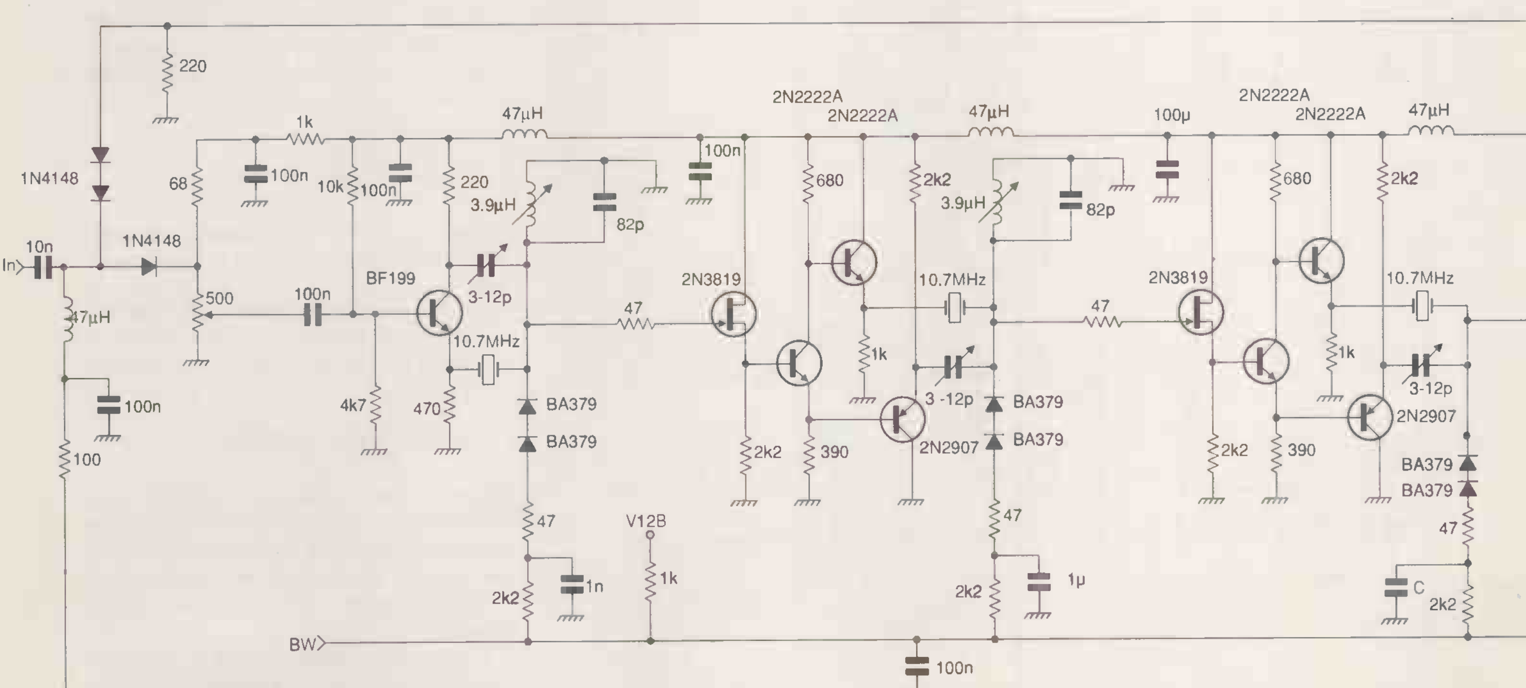
To make a stable, low noise and non-microphonic oscillator, use silvered-mica *NP0* capacitors, inductors with mechanically stable supports and a stable, well filtered power supply.

Remember to solder oscillator components to the board, or fix them using wax or adhesive. This will prevent microphonic effects and allow you to remove them if necessary.

Variable quartz filter

The quartz filter that determines bandwidth relies on the resistance of *PIN* diodes in parallel with the tuned circuit. Increasing current into the diodes decreases their equivalent resistance. It also decreases the ratio $Q=F/B$ between the centre frequency and the 3dB bandwidth.

If the variation of diode capacitance is negligible, they do not change F but increase B.



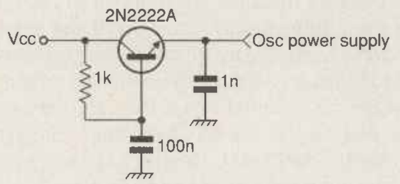


Fig. 9. Low impedance power supply. Input ac fluctuations are reduced by the 100nF capacitor.

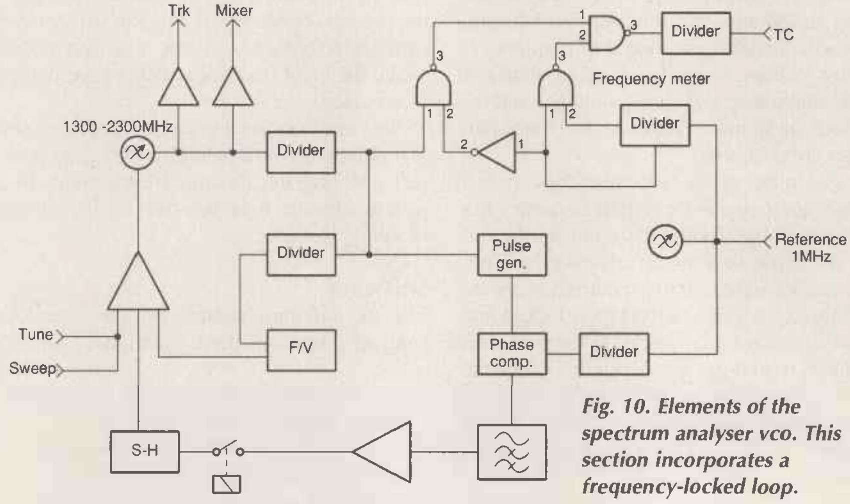


Fig. 10. Elements of the spectrum analyser vco. This section incorporates a frequency-locked loop.

In **Fig. 8**, trimmer capacitors compensate for asymmetry in the frequency response. The junction fet guarantees a high impedance to help obtain a high *Q*.

When implementing this circuit, it is necessary to select crystals that work in series fundamental mode, with identical frequencies and with minimum equivalent resistance.

Digital interface

Control voltages are produced by the digital interface. This comprises two *MAX500* quad 8bit serially-controlled d-to-a converters and two *MAX543* 12bit d-to-a converters. These generate voltages for tuning the vco and for sweeping and calibrating it.

Together with low noise op-amps, these d-to-a converters generate voltages to calibrate the vco and the third local oscillator. They also produce signals for tuning the third local oscillator, controlling bandwidth, calibrating gain and changing intermediate-frequency gain.

On the same board *ULN2004* drivers control the rf attenuator relays, the cut-off relay and close the vco phase-locked loop in the first local oscillator. A peak detector integrates the amplitude of four successive samples of the log amplifier prior to the a-to-d conversion. Sweeping is produced by a 12bit d-to-a converter, but on screen it is not possible to detect more than 500 horizontal steps. Moreover this integration can be used to increase signal to noise ratio and sensitivity.

Interfacing to a pc

I designed most of the control ICs on to a pc AT BUS expansion card. It holds an Analog Devices' *AD7821* fast a-to-d converter, a 12bit d-to-a converter, a triple programmable timer and an *8255* i/o interface.

One flat cable and two miniature coaxial cables transfer every digital control, analogue input to the a-to-d converter and sweep voltage to the digital interface board. This is not the best solution, but it is simple.

First local oscillator

Many of the spectrum analyser's parameters depend on local oscillator characteristics. The main technical specifications of this module are,

- Frequency range with a relatively constant amplitude from 1.3-2.3GHz,
- two output ports with power higher than +7dBm,
- phase lock capabilities with steps of 1MHz or lower,
- very low phase noise,
- linear transfer function from control voltage and output frequency.

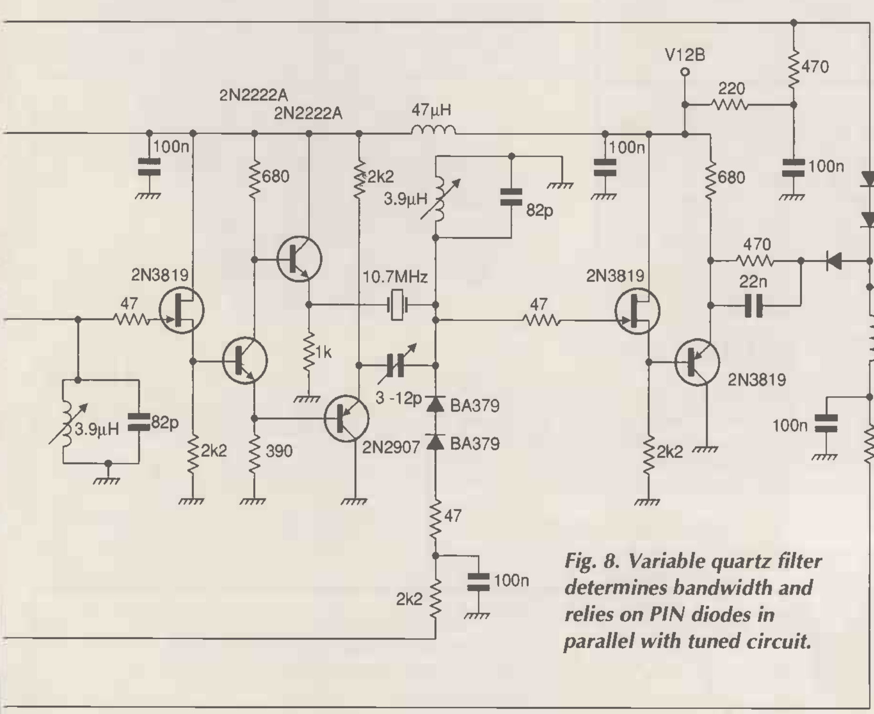


Fig. 8. Variable quartz filter determines bandwidth and relies on PIN diodes in parallel with tuned circuit.

Together these characteristics are difficult to achieve. If you do not have uhf components, instrumentation and experience in ultra high frequencies, you can waste a lot of time trying to sort out the oscillator. Certainly a yttrium-iron-garnet oscillator can solve many of these problems. But such oscillators are expensive and difficult to find.

A good alternative to a labour-intensive home made oscillator is a solid-state voltage-controlled crystal oscillator. Several manufacturers, including Avantek and Watkin Johnson, make small, uhf oscillator modules in packages similar to *TO5*. Such oscillators do not normally give the required power, but they do allow you to simplify and repeat the circuit characteristics.

When using this module, the power supply should have a low impedance between dc and the operating frequencies. To achieve this it is not sufficient to have very short connections to ground – even leadless ceramic capacitors. It is necessary to use an active buffer, **Fig. 9.**

To linearise the vco transfer function I have made a frequency-locked loop like the one shown in the internal feed back of **Fig. 10.** Output frequency is divided 2048 times before triggering a constant pulse generator.

If pulses are shorter than the triggering period, their number per second is proportional to the output frequency. Integrating these pulses, whose amplitude and duration is constant, gives a dc signal proportional to frequency. I use this voltage as feedback in an analogue adder, where tune and sweep voltages and the error voltage from the phased-locked loop comparator are connected.

To obtain low phase noise near the carrier it is better not to divide the output frequency too far. If you do, it is possible to transfer the stability and phase noise of the reference oscillator to the output signal. In my spectrum analyser, this only happens when the vco is locked and the sweep voltage is connected to the third local oscillator. Also if the low frequency vco in the third local oscillator is free running, it is relatively clean, and its phase noise is not detectable on the screen with a span of several megahertz.

Phase comparator

The phase comparator is made with a very fast pulse generator and a mixer that samples output frequency, divided by four. Using this solution, pulses are separated from the oscillator output with a cleaner spectrum spread, and amplitude on the phase-comparator can be kept constant.

By connecting a signal derived from the frequency-locked-loop divider to a 16bit divider it is possible to produce a frequency meter. It is possible to count how many pulses are required to bring the counter to zero using the pc. Since the precise counting period is known, derived from the reference oscillator, it is easy to calculate the input frequency with a good degree of accuracy.

The same frequency counting system is used to measure the variable 9MHz third local oscillator. Mixing the measured frequencies in a simple formula it is possible to display the receiving frequency.

Software

The pc software controlling the spectrum analyser comprises these functions:

- draw a graticule and reference numbers for the set parameters on screen,
- draw lines between the y axis samples, repaint colours and clear graticule elements from previous lines,
- read keyboard and optical encoder to determine functions requested,
- save measurement samples in memory for later disk storage,
- configure the pc so that 'Print Screen' key can start a print out.

Some of these functions are time critical because the 'time per division' must be independent from program cycle time. To execute the graphics functions mentioned fast enough for a real-time display, using serial and parallel ports on a standard pc can cause problems.

I tried small 386 assembly language routines and specific professional software, for example National's *LabWindows* and Hewlett Packard's *APPCAD*. Both produced good results in terms of speed and graphics.

My main program was written in Quick Basic. It is unpretentious, and is continuously undergoing modifications and updating. ■

In a subsequent article, Felice discusses set up, calibration and software details.

Further reading

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Wayne C. Ryder, 'High Performance Spectrum Analyser', *HAM Radio Magazine*, June 1977.

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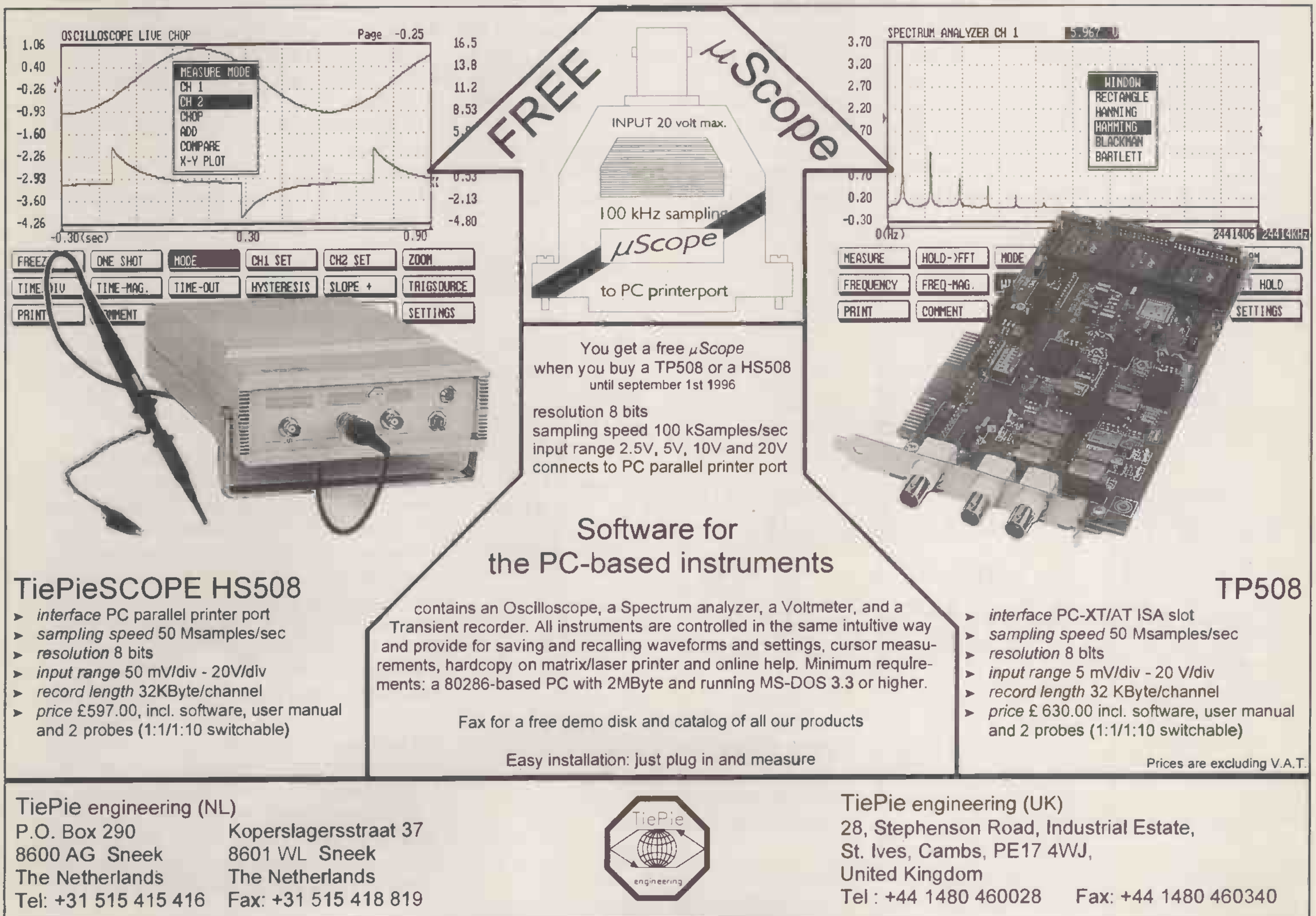

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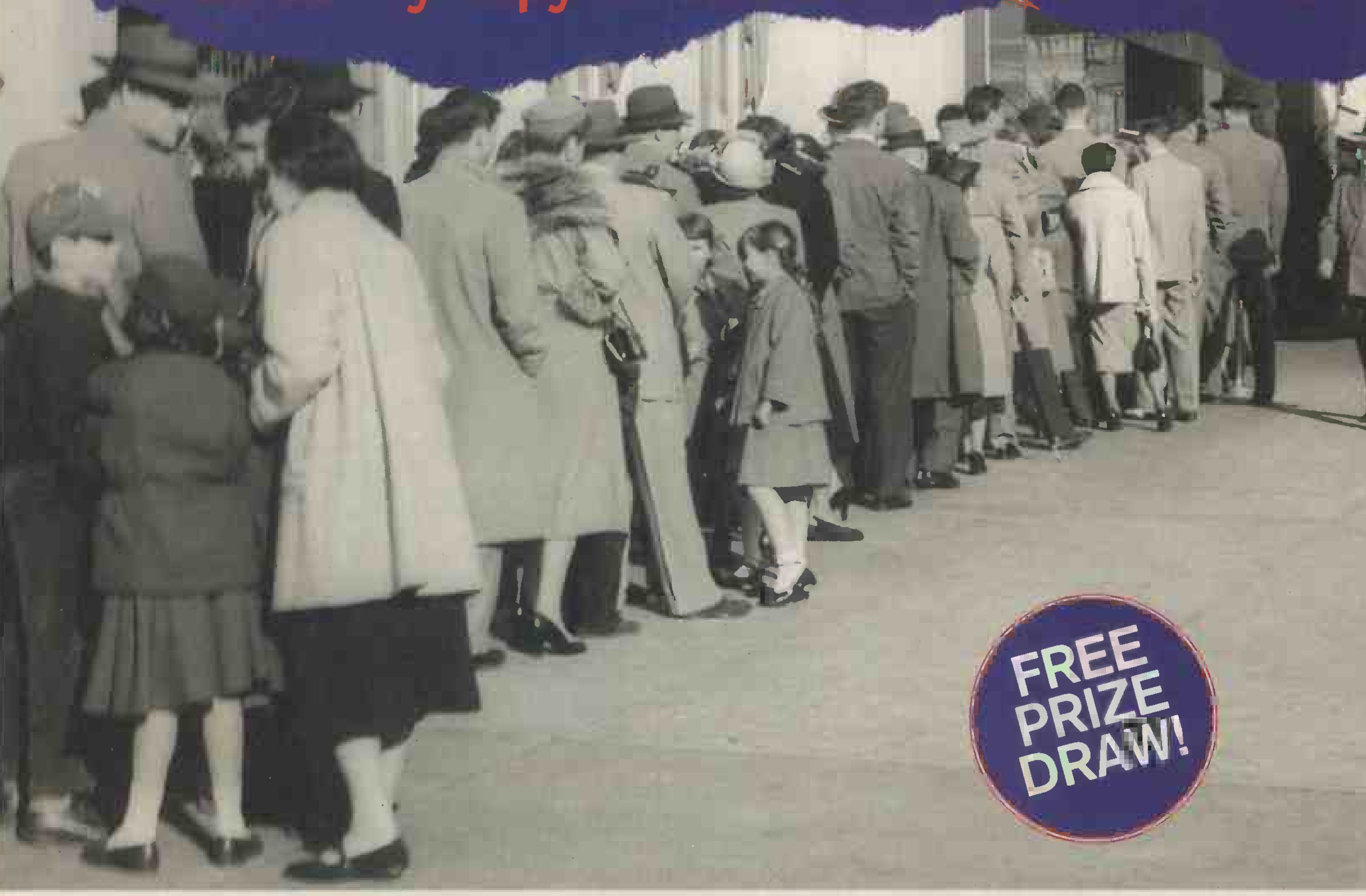

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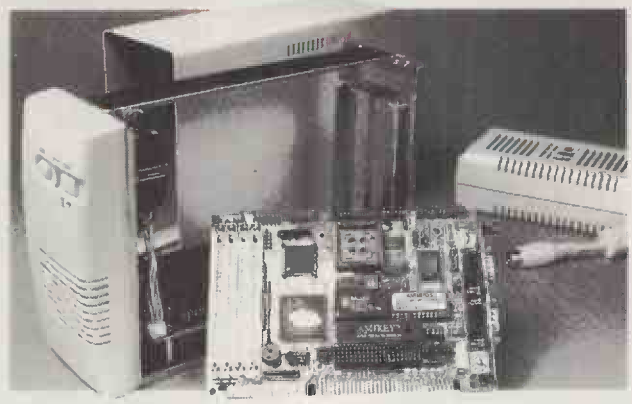

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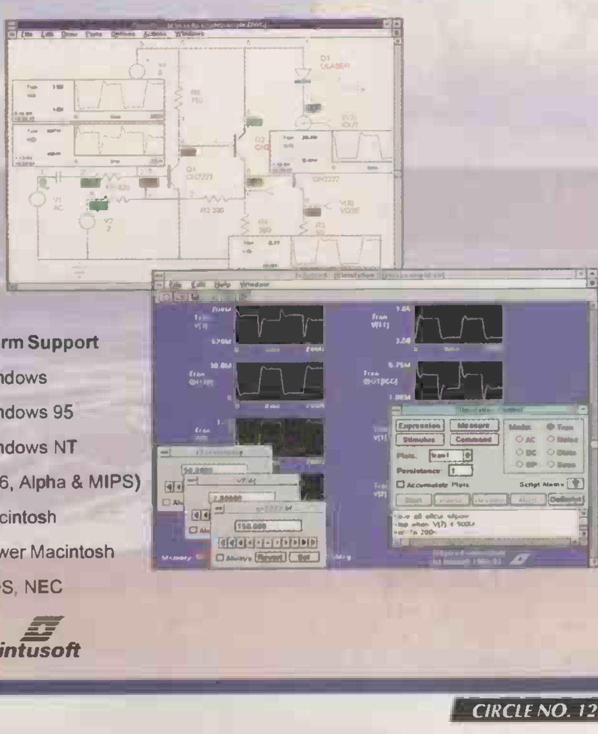

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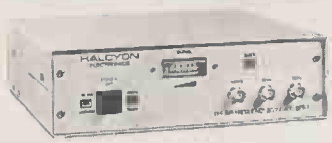

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Unipolar positive operation for the *DAC-08*

The *DAC-08* digital-to-analogue converter has excellent performance and provides complementary outputs. Its data sheet shows various schemes for using the outputs with external components to obtain bipolar or unipolar characteristics. There is, however, no apparent method of obtaining a unipolar *positive* output. The circuit shown for the positive low-impedance equivalent has no provision for complementary output. This circuit is a solution to the problem.

Basic bipolar operation is shown in the data sheet, reproduced in **Fig. 1**, and a modification of this, **Fig. 2**, provides the answer. Splitting the two 10kΩ resistors into two halves, with outputs taken from the junctions, effectively shifts the whole output positive by 10V, as indicated in the table.

With this scheme, unipolar positive and bipolar outputs are available from the same circuit.

S Ravindranathan
Naval Physical and Oceanographic Laboratory
Kochi India

Table. Output versus binary input for the unipolar d-to-a.

Input status	B_1	B_2	B_1	B_1	B_1	B_1	B_1	E_o	$\bar{E}_o$
Full scale	1	1	1	1	1	1	1	0.04	10.00
Full scale–lsb	1	1	1	1	1	1	0	0.08	9.96
Half scale–lsb	1	0	0	0	0	0	1	4.96	5.08
Half scale	1	0	0	0	0	0	0	5.00	5.04
Half scale–lsb	0	1	1	1	1	1	1	5.04	5.00
Zero scale+lsb	0	0	0	0	0	0	1	9.96	0.08
Zero scale	0	0	0	0	0	0	0	10.00	0.04

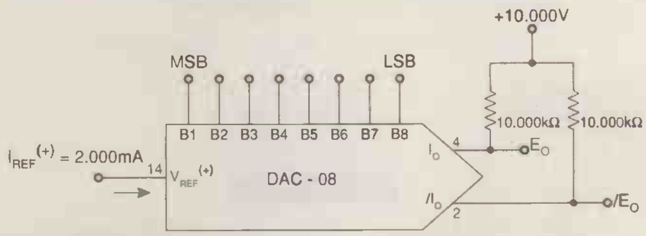

Fig. 1. Basic bipolar operation, as shown in Motorola's data sheet for the DAC-08.

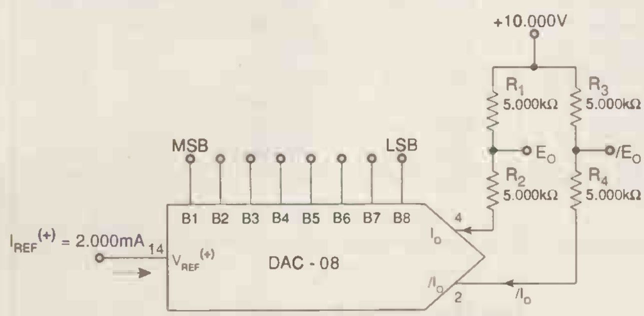

Fig. 2. Modifying the circuit of Fig.1 provides both unipolar positive and bipolar working at the same time.

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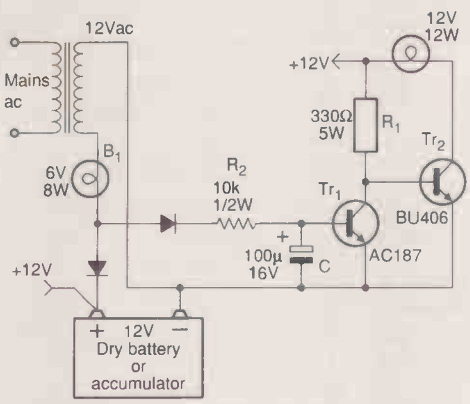
CIRCLE NO. 128 ON REPLY CARD

Trickle-charged emergency light



Emergency lights designed to switch on when the mains fails have the disadvantages that it can be expensive to repair them when necessary and to keep them in batteries. This design uses an old 12V car battery, but the circuit may be modified to take a 6V battery.

With normal mains operation, the battery charges through D_1, the 6V bulb indicating the fact. Since Tr_1 is bottomed by way of D_2 and the smoothing components CR_2, Tr_2 is turned off. Consequently the 12V lamp is off. A mains failure cuts Tr_1 off, so Tr_2 conducts and the 12V lamp comes on.

Transistor Tr_2 is a power type on a heat sink and the 12V bulb may be replaced by three 6V, 8W bulbs for a longer life.

Car battery is normally charged from the mains, powering the 12V emergency lamp during mains failure.

I Rahman
Islamabad
Pakistan

£100 WINNER

200MHz spectrum analyser displays to –75dB

Used with an ordinary oscilloscope, this circuit forms a spectrum analyser for the 0-200MHz range of frequencies. To simplify examination of the wanted frequency, span and centre frequency controls are arranged to make signals in the middle of the trace stay there as span decreases.

Amplifiers A_1 and A_2 produce a sawtooth waveform, symmetrical about the 12V rail, which is amplified in A_3 with control of amplitude for span and offset for centre frequency. The discharge pulse from A_2 for the integrator also goes to the oscilloscope as a timebase trigger.

Driven by the sawtooth, the Mini Circuits *POS-400* voltage-controlled oscillator provides a linear voltage/frequency output over the 180-380MHz range and drives the *SLB-1* double-balanced mixer

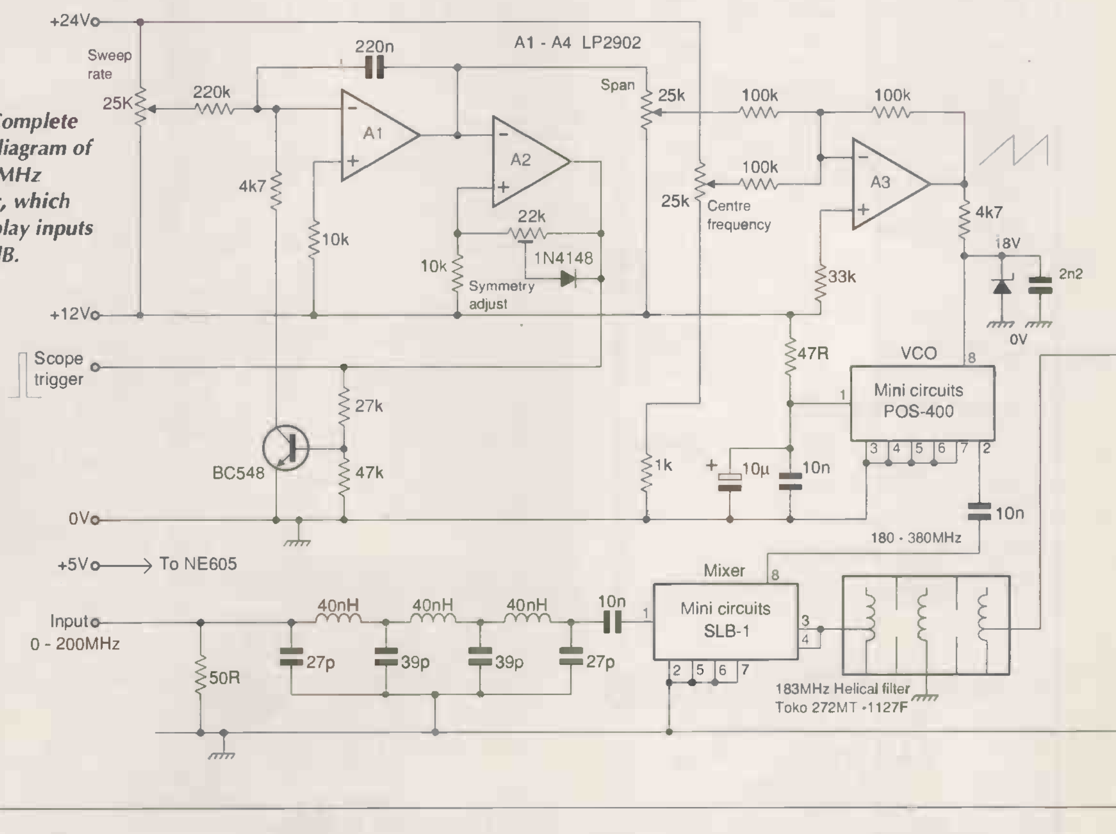


Fig. 1. Complete circuit diagram of the 200MHz analyser, which will display inputs at –75dB.

Electrostimulator

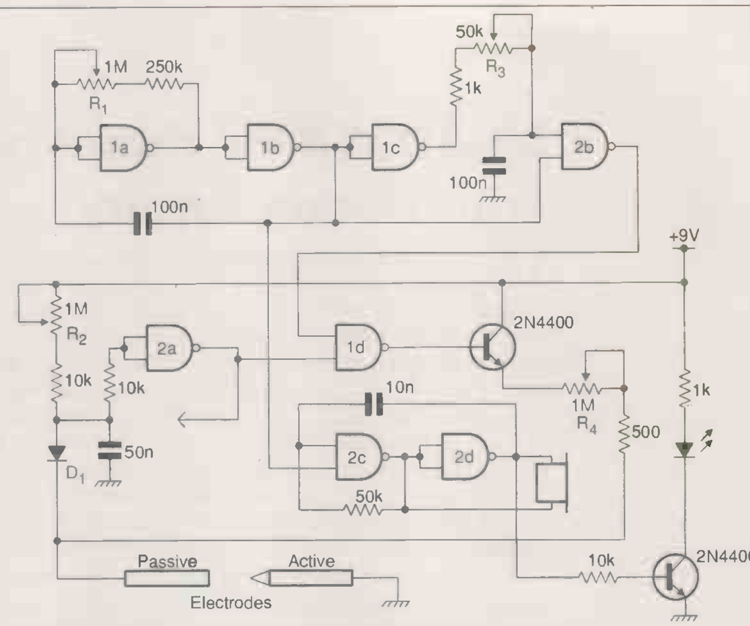
Providing a constant-frequency, variable-amplitude train of pulses in response to a probe coming in contact with a low-resistance biological point, this circuit is also usable as a voltage detector or to measure resistance.

Oscillator $IC_{1a,b}$ drives the monostable $IC_{1c,2b}$, this part of the circuit only operating when its voltage supply is provided by IC_{2a}. When the passive probe touches a biologically active point of low resistance, the output of IC_{2a} rises and turns on the oscillator, also opening gate IC_{1d}. Oscillator pulses now pass, via the amplitude control R_4, to the probe, being prevented from affecting the rest of the circuit by D_1. Resistor R_2 determines the input sensitivity and R_1 and R_3 are frequency and pulse width adjustments respectively.

To provide an indication of operation, particularly at low frequency, the IC_1 oscillator modulates a second oscillator in $IC_{2c,d}$, which drives the sounder, transistor and led.

Component values shown give a 10-150Hz train of 0.5 to 5ms pulses.

Vasiliy Borodai
Zaporozhje
Ukraine



Using c-mos ICs, this circuit emits a constant-frequency pulse train to stimulate biologically active points. No switching is needed, since it only operates when the probe touches the point.

directly, signal input to the mixer coming via the low-pass filter.

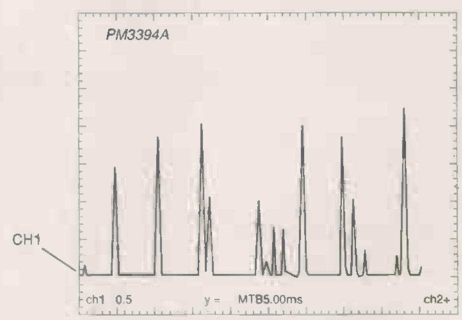
After filtering by the Toko *272MT-1127F*, mixer output is impedance matched to the *NE605*. This device converts down to a standard if of 10.7MHz, the local oscillator being a saw type. A voltage proportional to the log. of the internally amplified 10.7MHz if appears at pin 7 of the *NE605* and is buffered in A_4 to be used as the oscilloscope input.

Symmetry of response is maintained by the *CFSK* ceramic filters, which also determine the bandwidth.

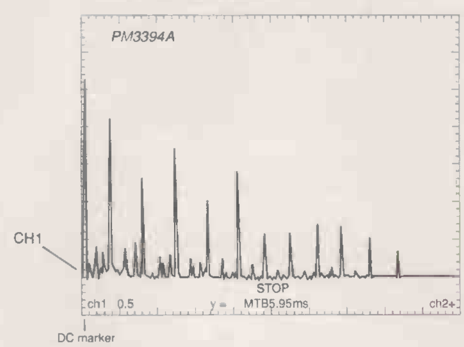
A limitation is the fairly slow response of the output of the *NE605*. It is usable, but reduces the amplitude of the display at faster sweep rates. It may be that the *NE625*, which is pin-compatible and faster, would improve matters.

Glyn Roberts
Walsall
West Midlands

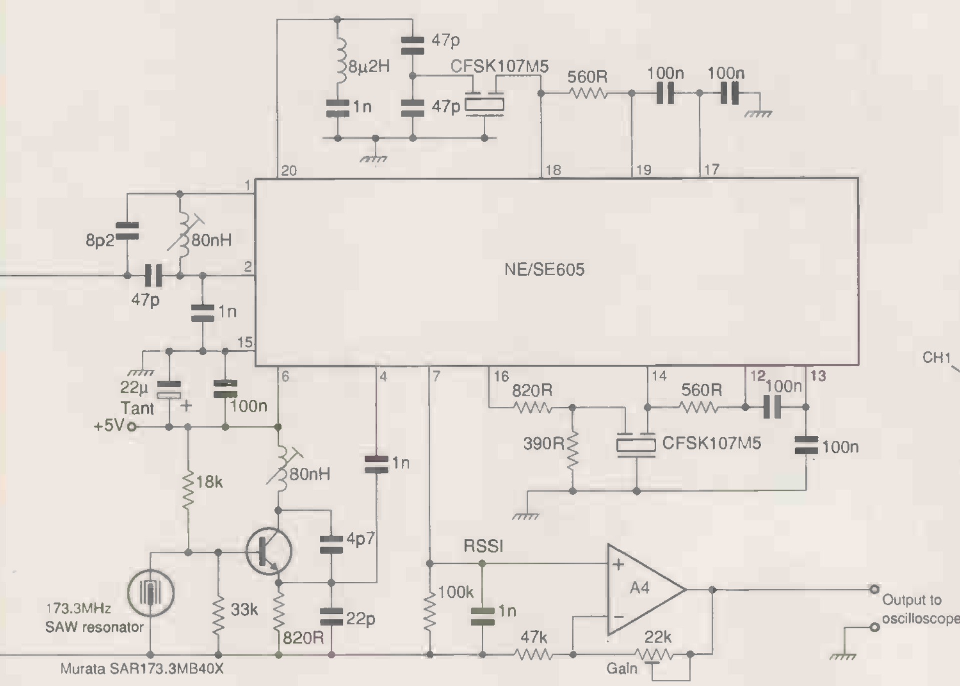
Spectrum of local fm broadcast band, 88 to 108MHz, top, and 20MHz square wave, demonstrating sweep linearity, bottom.



Y/Div: 500mV Timebase: 5.00ms Trace: ch1
Trigger: 10:35 Time: 07:56



Y/Div: 500mV Timebase: 5.95ms Trace: ch1
Trigger: 10:30 Time: 07:47 Date:



25-1025MHz signal generator with sweep facility

This very simply built generator is effectively a set of commercial voltage-controlled oscillators with some power and control circuitry. It provides good performance in a novel arrangement, which can be modified to suit individual needs.

Output is from 50Ω at 5dBm, varying about 1.5dBm over the frequency range, harmonics are at less than –20dBc and phase noise around –100dBc at 10kHz.

Two switched rails carry the tuning voltage, which may be adjusted on each by potentiometers or varied by an externally applied sawtooth for a sweep. A meter, driven by voltage followers, indicates the tuning voltage and therefore the frequency fairly roughly.

A set of seven oscillators from Mini Circuits covers the 25-1025MHz band in roughly 2:1 steps and forms the core of the circuit, each oscillator being followed by an attenuator to define the 50Ω impedance at the BNC outputs rather more exactly than do the oscillators. This also allows individual output levels to be adjusted, since they do vary somewhat. Again, the attenuators come from MiniCircuits.

Since, even if all the oscillators were to be switched into circuit at the same time, current requirement would be only 140mA, the power supply need only be fairly modest, although the tuning voltage must be well filtered to maintain a low noise level.

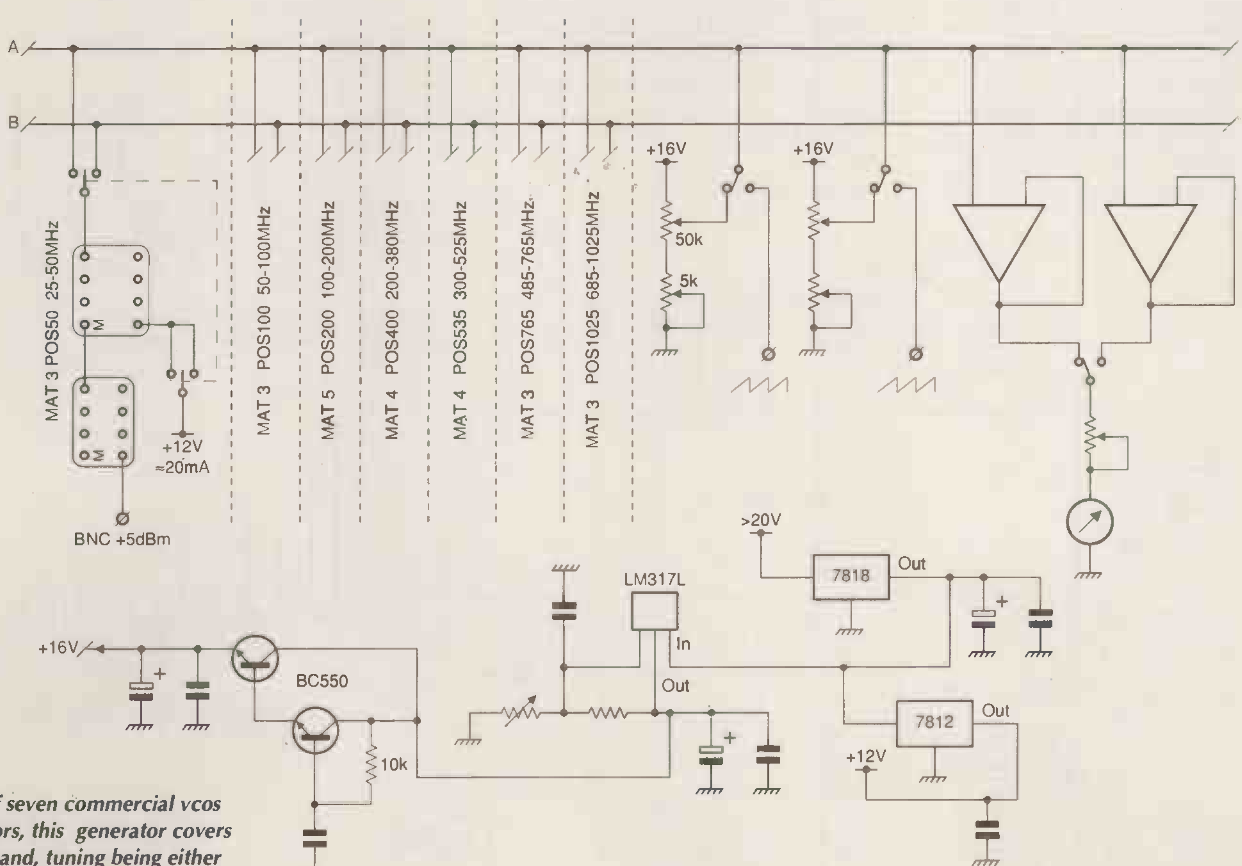
A BICC-Vero Eurocard *03-2989L* suits the circuit well. Note that a ground plane is essential.

Björn Nilsson
Mijas
Spain

Make sure that V+ is as clean as possible. Decouple each tuning port pin with 10nF but do not use an electrolytic capacitor – ed.

Special offer to *EW* readers

Electronics World readers can obtain a set of oscillators for this design at £60.65 excluding VAT. This represents over 10% discount on the normal price. For each *PATx* surface-mount attenuator (*MATx* equivalent) required add £2.95 excluding VAT. Send your order requesting one *KPOS2EW* set plus any attenuators you want at £2.95 each, together with a cheque or postal order payable to Mini Circuits, to Mini Circuits Europe, Dale House, Wharf Road, Frimley Green, Camberley, Surrey GU16 6LF. Credit card orders are acceptable. Phone 01252 835094, fax 01252 837010.



Using a set of seven commercial vcos and attenuators, this generator covers a very wide band, tuning being either by ten-turn potentiometers on either of two switched voltages or externally to give a sweep.

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DELL PC POWER SUPPLIES 145 watt, +5,-5,+12,-12, 150x150x85mm complete with switch, flyleads and IEC socket. SALE PRICE £9.99 ref EP55

1.44 DISC DRIVES Standard PC 3.5" drives but returns so they will need attention SALE PRICE £4.99 ref EP68

1.2 DISC DRIVES Standard 5.25" drives but returns so they will need attention SALE PRICE NOW ONLY £3.50 ref EP69

PP3 NICADS Unused but some storage marks. £4.99 ref EP52

DELL PC POWER SUPPLIES (Customer returns) Standard PC psu's complete with fly leads, case and fan. +12v,-12v,+5v,-5v SALE PRICE £1.99 EACH worth it for the bits alone! ref DL1. TRADE PACK OF 20 £29.95 Ref DL2.

GAS HOBS AND OVENS Brand new gas appliances, perfect for small flats etc. Basic 3 burner hob SALE PRICE £24.99 ref EP72. Basic small built in oven SALE PRICE £79 ref EP73

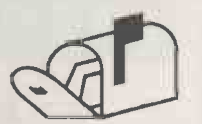
RED EYE SECURITY PROTECTOR 1,000 watt outdoor PIR switch SALE PRICE £6.99 ref EP57

ENERGY BANK KIT 100 6"x6" 6v 100mA panels, 100 diodes, connection details etc. £69.95 ref EF112.

PASTEL ACCOUNTS SOFTWARE, does everything for all sizes of businesses, includes wordprocessor, report writer, windowing, networkable up to 10 stations, multiple cash books etc. 200 page comprehensive manual. 90 days free technical support (0345-326009 try before you buy!) Current retail price is £129, SALE PRICE £9.95 ref SA12. SAVE £120!!!

COMPLETE PC 200 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts. New and boxed, UK made Provides up to 5 mins running time in the event of complete power failure to allow you to run your system down correctly. LAST FEW TO CLEAR AT £49 SAVE £30 ref LOT61

BIG BROTHER PSU Cased PSU, 6v 2A output, 2m o/p lead, 1.5m input lead, UK made, 220v. SALE PRICE £4.99 REF EP7



Check out our WEB SITE

http://www.pavilion.co.uk/bull-electrical

RACAL MODEM BONANZA! 1 Racal MPS1223 1200/75 modem, telephone lead, mains lead, manual and comms software, the cheapest way onto the net! all this for just £13 ref DEC13.

4.5mw LASER POINTER. BRAND NEW MODEL NOW IN STOCK!, supplied in fully built form (looks like a nice pen) complete with handy pocket clip (which also acts as the on/off switch.) About 50 metres range! Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. just £39.95 ref DEC49 TRADE PRICE £28 MIN 10 PIECES

BULL TENS UNIT Fully built and tested TENS (Transcutaneous Electrical Nerve Stimulation) unit, complete with electrodes and full instructions. TENS is used for the relief of pain etc in up to 70% of sufferers. Drug free pain relief, safe and easy to use, can be used in conjunction with analgesics etc. £49 Ref TEN/1

RUSSIAN MONOCULARS Amazing 20 times magnification, coated lenses, carrying case and shoulder strap £29.95 REF BAR73

PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware.. Ideal for laptops or a cheap upgrade. Supplied in kit form for home assembly. SALE PRICE £25 REF SA34

EMERGENCY LIGHTING UNIT Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8AH lead acid req'd. (secondhand) £4 ref MAG4P11.

YUASHA SEALED LEAD ACID BATTERIES Two sizes currently available this month. 12v 15AH at £18 ref LOT8 and 6v 10AH (suitable for emergency lights above) at just £6 ref LOT7.

ELECTRIC CAR WINDOW DE-ICERS Complete with cable, plug etc SALE PRICE JUST £4.99 REF SA28

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt £8.99 REF SA25.

ECLATRON FLASH TUBE As used in police car flashing lights etc, full spec supplied, 60-100 flashes a min. £6.99 REF SA15B.

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

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250 PORTLAND ROAD, HOVE, SUSSEX BN3 5QT. (ESTABLISHED 50 YEARS).

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24v AC 96WATT Cased power supply. New. £9.99 REF SA40

MICRODRIVE STRIPPERS Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. SALE PRICE JUST £4.99 FOR FIVE REF SA26

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit SALE PRICE JUST £4.99 REF SA27

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. SALE PRICE £49 REF SA16B

PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

13.8V 1.9A PSU cased with leads. Just £9.99 REF MAG10P3

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C5 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

PHONE CABLE AND COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance utilizing the serial ports. Complete kit £8.99. Ref comp1.

VIEWDATA SYSTEMS made by Phillips, complete with internal 1200/75 modem, keyboard, psu etc RGB and composite outputs, menu driven, autodialler etc. SALE PRICE £12.99 REF SA18

AIR RIFLES .22 As used by the Chinese army for training puposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

PLUG IN POWER SUPPLY SALE FROM £1.50 Plugs in to 13A socket with output lead. three types available. 9vdc 150mA £1.50 ref SA19, 9vdc 200mA £2.00 ref SA20, 6.5vdc 500mA £2 ref SA21.

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

***MINATURE RADIO TRANSCEIVERS** A pair of walkie talkies with a range up to 2km in open country. Units measure 22x52x155mm. Including cases and earp'ces. 2xPP3 req'd. £30.00 pr. REF: MAG30

***FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £15 REF: EF62 (kit) Transmits to any FM radio.

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER COMPLETE WITH COINSLOT MECHANISMS originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? SALE PRICE JUST £2.50 REF SA23

GAT AIR PISTOL PACK Complete with pistol, darts and pellets £12.95 Ref EF82B extra pellets (500) £4.50 ref EF80.

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. SALE PRICE £4.99 REF SA24.

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

MIXED GOODIES BOX OF MIXED COMPONENTS WEIGHING 2 KILOS YOURS FOR JUST £5.99

4X28 TELESCOPIC SIGHTS Suitable for all air rifles, ground lenses, good light gathering properties. £19.95 ref R/7.

RATTLE BACKS Interesting things these, small piece of solid perspex like material that if you try to spin it on the desk it only spins one way! In fact if you spin it the 'wrong' way it stops of its own accord and go's back the other way! £1.99 ref GI/J01.

GYROSCOPES Remember these? well we have found a company that still manufactures these popular scientific toys, perfect gift or for educational use etc. £6 ref EP70

HYPOTHERMIA SPACE BLANKET 215x150cm aluminised foil blanket. reflects more than 90% of body heat. Also suitable for the construction of two way mirrors! £3.99 each ref O/L041.

LENSTATIC RANGER COMPASS Oil filled capsule, strong metal case, large luminous points. Sight line with magnifying viewer. 50mm dia, 86gm. £10.99 ref O/K604.

RECHARGE ORDINARY BATTERIES UP TO 10 TIMES! With the Battery Wizard! Uses the latest pulse wave charge system to charge all popular brands of ordinary batteries AAA, AA, C, D, four at a time! Led system shows when batteries are charged, automatically rejects unsuitable cells, complete with mains adaptor. BS approved. Price is £21.95 ref EP31.

TALKING WATCH Yes, it actually tells you the time at the press of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £7.99 ref EP26.

PHOTOGRAPHIC RADAR TRAPS CAN COST YOU YOUR LICENCE! The new multiband 2000 radar detector can prevent even the most responsible of drivers from losing their licence! Adjustable audible alarm with 8 flashing leds gives instant warning of radar zones. Detects X, K, and Ka bands, 3 mile range, 'over the hill' 'around bends' and 'rear trap facilities. micro size just 4.25"x2.5"x.75", Can pay for itself in just one day! £79.95 ref EP3.

SANYO NICAD PACKS 120mmx14mm 4.8v 270 maH suitable for cordless phones etc. Pack of 2 just £5 ref EP78.

3" DISCS As used on older Amstrad machines, Spectrum plus3's etc £3 each ref BAR400.

STEREO MICROSOPES BACK IN STOCK Russian, 200x complete with lenses, lights, filters etc etc very comprehensive microscope that would normally be around the £700 mark, our price is just £299 (full money back guarantee) full details in catalogue. Ref 95/300.

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200 WATT INVERTERS Nicely cased units 12v input 240v output 150watt continuous, 200 max. £49 ref LOT62.

6.8MW HELIUM NEON LASERS New units, £65 ref LOT33

COINSLOT TOKENS You may have a use for these? mixed bag of 100 tokens £10 ref LOT20.

PORTABLE X RAY MACHINE PLANS Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. Not a toy or for minors! £6/set. Ref F/XP1.

TELEKINETIC ENHANCER PLANS Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing phychic phenomenon. £4/set Ref F/TKE1.

ELECTRONIC HYPNOSIS PLANS & DATA This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set. Ref F/EH2.

GRAVITY GENERATOR PLANS This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means- cause it to levitate. £10/set Ref F/GRA1.

WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects, 'Plasma in a jar', St Elmo's fire, Corona, excellent science project or conversation piece. £5/set Ref F/BTC1/LG5.

COPPER VAPOUR LASER PLANS Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commision of NEGEV in Israel. £10/set Ref F/CVL1.

VOICE SCRAMBLER PLANS Minature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/VS9.

PULSED TV JOKER PLANS Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED. £8/set Ref F/TJ5.

BODYHEAT TELESCOPE PLANS Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.

BURNING, CUTTING CO2 LASER PLANS Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LC7.

MYSTERY ANTI GRAVITY DEVICE PLANS Uses simple concept. Objects float in air and move to the touch. Defies gravity, amazing gift, conversation piece, magic trick or science project. £6/set Ref F/ANT1K.

ULTRASONIC BLASTER PLANS Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquides. Many cleaning uses for PC boards, jewllery, coins, small parts etc. £6/set Ref F/ULB1.

ULTRAHIGH GAIN AMP/STETHOSCOPIC MIKE/SOUND AND VIBRATION DETECTOR PLANS Ultrasensitive device enables one to hear a whole new world of sounds. Listen through walls, windows, floors etc. Many applications shown, from law enforcement, nature listening, medical heartbeat, to mechanical devices. £6/set Ref F/HGA7

ANTI DOG FORCE FIELD PLANS Highly effective circuit produces time variable pulses of accoustical energy that dogs cannot tolerate £6/set Ref F/DOG2

LASER BOUNCE LISTENER SYSTEM PLANS Allows you to hear sounds from a premises without gaining access. £12/set Ref F/LLIST1

LASER LIGHT SHOW PLANS Do it yourself plans show three methods. £6 Ref F/LLS1

PHASOR BLAST WAVE PISTOL SERIES PLANS Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PSP4

INFINITY TRANSMITTER PLANS Telephone line grabber/ room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/TELEGRAB.

BUG DETECTOR PLANS Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/BD1.

ELECTROMAGNETIC GUN PLANS Projects a metal object a considerable distance-requires adult supervision £5 ref F/EML2.

ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND! £5/set Ref F/EMA1.

PARABOLIC DISH MICROPHONE PLANS Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5

2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS Operates on 9-12vdc, many possible experiments. £10 Ref F/HVM7/

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER ST W'HAMPTON TEL 01902 22039

INFINITY TRANSMITTERS The ultimate 'bug' fits to any phone or line, undetectable, listen to the conversations in the room from anywhere in the world! 24 hours a day 7 days a week! just call the number and press a button on the mini controller (supplied) and you can hear everything! Monitor conversations for as long as you choose £249 each, complete with leads and mini controller! Ref LOT9. Undetectable with normal RF detectors, fitted in seconds, no batteries required, lasts forever!

SWITCHED MODE PSU'S 244 watt, +5 32A, +12 6A, -5 0.2A, -12 0.2A. There is also an optional 3.3v 25A rail available. 120/240v I/P. Cased, 175x90x145mm. IEC inlet Suitable for PC use (6 d/drive connectors 1 m/board). £10 ref PSU1.

VIDEO PROCESSOR UNITS?/6v 10AH BATTS/12V 8A TX Not too sure what the function of these units is but they certainly make good strippers! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear. Inside 2 x 6v 10AH sealed lead acid batts, pcb's and a 8A? 12v torroidial transformer (mains in). Condition not known, may have one or two broken knobs due to poor storage. £17.50 ref VP2

RETRON NIGHT SIGHT Recognition of a standing man at 300m in 1/4 moonlight, hermatically sealed, runs on 2 AA batteries, 80mm F1.5 lens, 20mw infrared laser included. £325 ref RETRON.

MINI FM TRANSMITTER KIT Very high gain preamp, supplied complete with FET electret microphone. Designed to cover 88-108 Mhz but easily changed to cover 63-130 Mhz. Works with a common 9v (PP3) battery. 0.2W RF. £7 Ref 1001.

3-30V POWER SUPPLY KIT Variable, stabilized power supply for lab use. Short circuit protected, suitable for profesional or amateur use 24v 3A transformer is needed to complete the kit. £14 Ref 1007.

1 WATT FM TRANSMITTER KIT Supplied with piezo electric mic. 8-30vdc. At 25-30v you will get nearly 2 watts! £12 ref 1009.

FM/AM SCANNER KIT Well not quite, you have to turn the knob your self but you will hear things on this radio that you would not hear on an ordinary radio (even TV). Covers 50-160mhz on both AM and FM. Built in 5 watt amplifier, inc speaker. £15 ref 1013.

3 CHANNEL SOUND TO LIGHT KIT Wireless system, mains operated, separate sensitivity adjustment for each channel, 1,200 w power handling, microphone included. £14 Ref 1014.

4 WATT FM TRANSMITTER KIT Small but powerful FM transmitter, 3 RF stages, microphone and audio preamp included. £20 Ref 1028.

STROBE LIGHT KIT Adjustable from 1-60 hz (a lot faster than conventional strobes). Mains operated. £16 Ref 1037.

LIQUID LEVEL DETECTOR KIT Useful for tanks, ponds, baths, rain alarm, leak detector etc. Will switch 2A mains. £5 Ref 1081.

COMBINATION LOCK KIT 9 key, programmable, complete with keypad, will switch 2A mains. 9v dc operation. £10 ref 1114.

PHONE BUG DETECTOR KIT This device will warn you if somebody is eavesdropping on your line. £6 ref 1130.

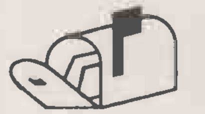
ROBOT VOICE KIT Interesting circuit that distorts your voice! adjustable, answer the phone with a different voice! 12vdc £9 ref 1131

TELEPHONE BUG KIT Small bug powered by the 'phone line, starts transmitting as soon as the phone is picked up! £8 Ref 1135.

3 CHANNEL LIGHT CHASER KIT 800 watts per channel, speed and direction controls supplied with 12 LEDS (you can fit triacs instead to make kit mains, not supplied) 9-12vdc £17 ref 1026.

12V FLOURESCENT LAMP DRIVER KIT Light up 4 foot tubes from your car battery! 9v 2a transformer also required. £8 ref 1069.

VOXSWITCH KIT Sound activated switch ideal for making bugging tape recorders etc, adjustable sensitivity. £8 ref 1073.



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PREAMP MIXER KIT 3 input mono mixer, sep bass and treble controls plus individual level controls, 18vdc, input sens 100mA. £15 ref 1052.

METAL DETECTOR KIT Range 15-20cm, complete with case, 9vdc. £8 ref 1022.

SOUND EFFECTS GENERATOR KIT Produces sounds ranging from bird chips to sirens. Complete with speaker, add sound effects to your projects for just £9 ref 1045.

15 WATT FM TRANSMITTER (BUILT) 4 stage high power, preamp required 12-18vdc, can use ground plane, yagi or open dipole. £69 ref 1021.

HUMIDITY METER KIT Builds into a precision LCD humidity meter, 9 ic design, pcb, lcd display and all components included. £29

PC TIMER KIT Four channel output controlled by your PC, will switch high current mains with relays (supplied). Software supplied so you can program the channels to do what you want whenever you want. Minimum system configeration is 286, VGA, 4.1,640k, serial port. hard drive with min 100k free. £24.99

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DIVINING RODS Expensive technology cannot challenge the fool proof art of water divining, passed down from generation to generation. Seeing is believing. Use in the home, garden, countryside or desert, it's divinely simple! £4.99 a pair ref E/3.

HUGE BUBBLE MAKING KIT You'll be amazed at the the size of the bubbles you can acheive with this bubble making kit. Once you have got the knack it is possible to make bubbles of up to 40 feet long. £11.99 ref E/9.

FM CORDLESS MICROPHONE This unit is an FM broadcasting station in minature, 3 transistor transmitter with electret condenser mic+fet amp design result in maximum sensitivity and broad frequency response. 90-105mhz, 50-1500hz, 500 foot range in open country! PP3 battery required. £15.00 ref 15P42A.

MAGNETIC MARBLES They have been around for a number of years but still give rise to curiosity and amazement. A pack of 12 is just £3.99 ref GI/R20

STETHOSCOPES A fully functioning stethoscope for all those intricate projects. Enables you to listen to motors, pipes, heartbeats, walls, insects etc. £6 ref MAR6P6.

NICKEL PLATING KIT Proffesional electroplating kit that will transform rusting parts into showpieces in 3 hours! Will plate onto steel, iron, bronze, gunmetal, copper, welded, silver soldered or brazed joints. Kit includes enough to plate 1,000 sq inches. You will also need a 12v supply, a container and 2 12v light bulbs. £39.99 ref NIK39.

Minature adjustable timers, 4 pole c/o output 3A 240v,
HY1230S, 12vDC adjustable from 0-30 secs. £4.99
HY1260M, 12vDC adjustable from 0-60 mins. £4.99
HY2405S, 240v adjustable from 0-5 secs. £4.99
HY24060m, 240v adjustable from 0-60 mins. £6.99

BUGGING TAPE RECORDER Small voice activated recorder, uses micro cassette complete with headphones. £28.99 ref MAR29P1.

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

9v DC POWER SUPPLY Standard plug in type 150ma 9v DC with lead and DC power plug. price for two is £2.99 ref AUG3P4.

COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 **REF: MAG8P2.**

FUTURE PC POWER SUPPLIES These are 295x135x60mm, 4 drive connectors 1 mother board connector. 150watt, 12v fan, iec inlet and on/off switch. £12 Ref EF6.

VENUS FLYTRAP KIT Grow your own carnivorous plant with this simple kit £3 ref EF34.

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. Bargain price just £5.99 ea REF MAG6P12.

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

ROCK LIGHTS Unusual things these, two pieces of rock that glow when rubbed together! belived to cause rain! £3 a pair Ref EF29.

3' by 1' AMORPHOUS SOLAR PANELS 14.5v, 700mA 10 watts, aluminium frame, screw terminals, £44.95 ref MAG45.

ELECTRONIC ACCUPUNCTURE KIT Builds into an electronic version instead of needles! good to experiment with. £7 ref 7P30

SHOCKING COIL KIT Build this little battery operated device into all sorts of things, also gets worms out of the ground! £7 ref 7P36.

FLYING PARROTS Easily assembled kit that builds a parrot that actualy flaps its wings and flies! 50 m range £6 ref EF2.

HIGH POWER CATAPULTS Hinged arm brace for stability, tempered steel yoke, super strength latex power bands. Departure speed of ammunition is in excess of 200 miles per hour! Range of over 200 metres! £7.99 ref R/9.

BALLON MANUFACTURING KIT British made, small blob blows into a large, longlasting balloon, hours of fun! £3.99 ref GI/E99R

9-0-9V 4A TRANSFORMERS, chassis mount. £7 ref LOT19A.

2.5 KILOWATT INVERTERS, Packed with batteries etc but as they weigh about 100kg CALLERS ONLY! £120.

MEGA LED DISPLAYS Build your self a clock or something with these mega 7 seg displays 55mm high, 38mm wide. 5 on a pcb for just £4.99 ref LOT16 or a bumper pack of 50 displays for just £29 ref LOT17.

CLEARANCE SECTION, MINIMUM ORDER £15, NO TECHNICAL DETAILS AVAILABLE, NO RETURNS, TRADE WELCOME.

2000 RESISTORS ON A REEL (SAME VALUE) 99P REF BAR340
AT LEAST 200 CAPACITORS (SAME VALUE 99P REF BAR342
INFRA RED REMOTE CONTROLS JUST 99P REF BAR333
CIRCUIT BREAKERS, OUR CHOICE TO CLEAR 99P REF BAR335
MICROWAVE CONTROL PANELS TO CLEAR £2 REF BAR 329
2 TUBES OF CHIPS(2 TYPES OUR CHOICE) 90P REF BAR305
LOTTERY PREDICTOR MACHINE!! JUST £1.50 REF BAR313
HELLA L/ROVER ELECTRIC H/LAMP LEVELLER £2 REF BAR311
SINCLAIR C5 16" TYRES TO CLEAR AT JUST 75P REF BAR318
LARGE MAINS MOTORS (NEW) TO CLEAR AT 75P REF BAR310
MODEMS ETC FOR STRIPPING £2.50 EACH REF BAR324
110V LARGE MOTORS (NEW) TO CLEAR AT 50P REF BAR332
MODULATOR UNITS UNKNOWN SPEC JUST 50P REF BAR323
GX4000 GAMES COSOLES JUST £4 REF BAR320
SMART CASED MEMORY STORAGE DEVICE, LOADS OF BITS INSIDE, PCB, MOTOR, CASE ETC. BUMPER PACK OF 5 COMPLETE UNITS TO CLEAR AT £2.50(FOR 5) REF BAR 330.
2 CORE MAINS CABLE 2M LENGTHS PACK OF 4 £1 REF BAR337
PC USER/BASIC MANUALS, LOADS OF INFO. £1 REF BAR304
PCB STRIPPERS TO CLEAR AT 2 FOR 99P REF BAR341
3 M 3CORE MAINS CABLE AND 13A PLUG. 60P REF BAR325

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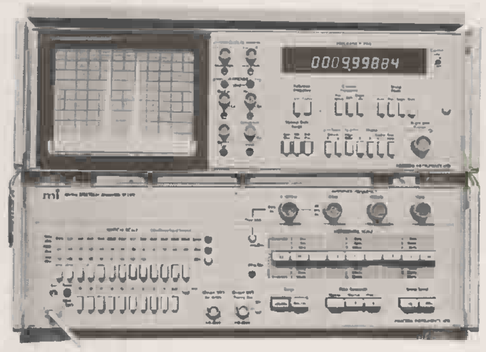

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CIRCLE NO. 135 ON REPLY CARD

Simulation for mixed signals

Bashir Al-Hashimi explains how mixed-mode circuit simulation packages differ from their solely analogue or digital predecessors.

Circuit simulation packages have become an important part of the design and implementation cycle of electronic systems. The result is fewer prototypes, shorter design cycle, and significantly better quality products.

Simulation packages divide into three types: analogue, digital and mixed signal simulators. Almost all analogue simulators are based on the popular Spice – an acronym for simulation program with integrated circuit emphasis. Spice was developed in the 1970s in the University of California. This type of simulator predicts the frequency and time response of analogue circuits.

The simulation results are graphs of amplitude, phase against frequency in the case of frequency analysis and graphs of amplitude against time for transient analysis. This shows that Spice can be used to simulate the functions of network analysers and oscilloscopes in practice.

A digital simulator enables the designer to perform a timing analysis of a digital circuit. The result is a timing diagram or a truth table of the circuit. In practice, this is the similar to using a logic analyser.

As circuits increase in complexity, it is likely that a mix of analogue and digital parts is used for implementation. To predict the performance of such circuits, mixed signal simulators are needed. This article aims to provide an introduction to this type of simulation through a detailed worked example. The simulator PSpice A/D from MicroSim[1] is used for demonstration purposes. For an introduction to circuit simulation and PSpice, read reference 2.

Types of mixed-signal simulator

Mixed signal simulators are basically divided into two types: native and glued. A glued simulator consists of a separate analogue and digital simulators combined through an interface software which controls data flow between the two simulators.

An example of glued simulator is *Continuum* from Mentor Graphics. Glued simulators are aimed primarily at systems with large number of analogue and digital parts. Also, they provide designer with the opportunity to integrate their favourite simulators.

A native simulator on the other hand consists of one simulator which performs mixed signal simulation. Examples are *PSpice A/D* and *Saber* from Analogy. When simulating systems that contain large analogue circuitry and small number of digital parts, a native simulator is usually a better choice. **Table 1** is a list of some commercially available mixed signal simulators.

Table 1. Comparison of some commercial mixed-signal simulators.

Vendor	Name	Type	Platform
Analogy	Saber	Native	Workstations
Intusoft	ICAP/4	Native	PCs
Mentor Graphics	Continum	Glued	Workstations
Microsim	PSpice A/D	Native	Workstations, PCs
Viewlogic	Mixed-signal Designer	Glued	Workstations

Mixed signal simulator principles

Analogue simulators recognise only analogue nodes where all components connected to the node are analogue. Similarly, digital simulators deal only with digital nodes. A mixed signal simulator on the other hand recognises three types of nodes, namely analogue, digital and interface.

An interface node occurs when a combination of analogue and digital components are connected to it as shown in **Fig. 1**. Here, node 1 is an analogue node, while nodes 2 and 3 are interface nodes. A mixed signal simulator must translate interface nodes into purely analogue or digital nodes. The translation is achieved using different techniques depending on the simulator. The *Saber* simulator, for example, uses special models called Hypermodels for the translation.

The *PSpice A/D* simulator on the other hand, achieves the translation using 1-bit analogue/digital, a-to-d, and digital/analogue, d-

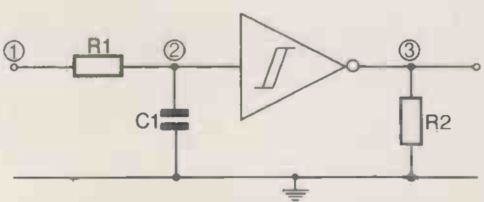

Fig. 1. In mixed-mode simulation, when a combination of analogue and digital components are used, an interface node occurs.

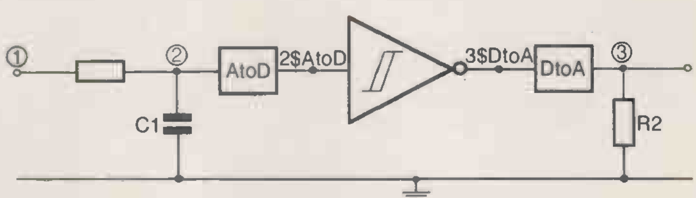

Fig. 2. This shows the circuit in Fig. 1 after PSpice has inserted a-to-d and d-to-a interface subcircuits.

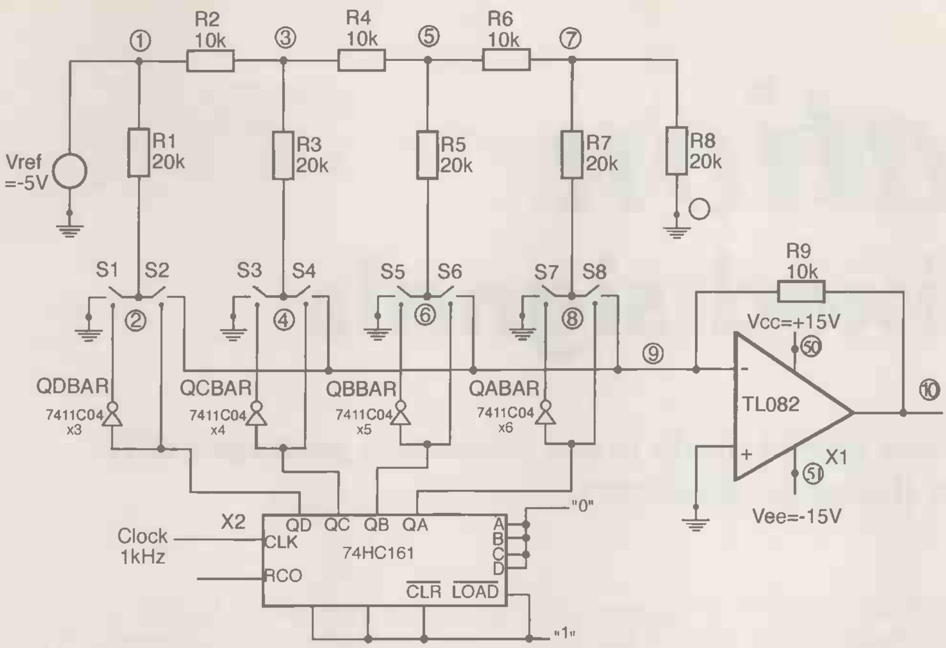

Fig. 3. Mixed-mode circuit example for producing ramp waveforms.

to-a, interface subcircuits. The function of both the hypermodels and the 1-bit a-to-d and d-to-a subcircuits is to change analogue voltages and impedances to digital states (0, 1, X, Z...) and *vice versa*. The simulator automatically inserts the appropriate subcircuits between analogue and digital parts.

For example, **Fig. 2** shows the circuit of Fig. 1, after *PSpice* has inserted a-to-d and d-to-a interface subcircuits. Nodes 2 and 3 are now purely analogue nodes. As Fig. 2 shows that the simulator has created two new digital nodes designated 2$AtoD and 3$DtoA. The *PSpice* symbol $ represents new nodes occurring as a result of a-to-d and d-to-a interface subcircuits.

For more information on how *PSpice* creates and name these nodes, see reference 2.

Entering circuit details

In order to perform a circuit simulation, the circuit must first be described to the simulator. There are usually two methods of achieving this task, one a netlist, the other schematic capture. The choice of circuit entry depends largely on user preference, with both methods requiring some time to learn. However, it is generally accepted that understanding the basic rules of creating netlists often allow a better appreciation of the simulation process and principles in particular for analogue simulation.

The *PSpice A/D* simulator supports both types of circuit entry, with the dos version providing the netlist entry, while the windows version provides the schematic capture entry. In this article, the netlist method is used. Note, however, that the simulation of complex digital circuits requires the use of schematic capture. To demonstrate mixed signal simulation, consider the following example.

A mixed simulation example

Figure 3 shows a circuit for producing ramp waveforms[3]. Outputs of the four-bit counter, QD QC QB QA, determine the position of switches S_1, S_2, S_3... Logic zero connects the switch to ground, while logic one connects the switch to the inverting input of the amplifier.

The amplifier acts as a current-to-voltage converter. Here, the simulator is used to obtain the amplifier output voltage as the four-bit counter goes through its different 16 states. **Listing 1** gives the *PSpice* netlist of the circuit.

First consider the description of the analogue parts. The listing shows that the resistors

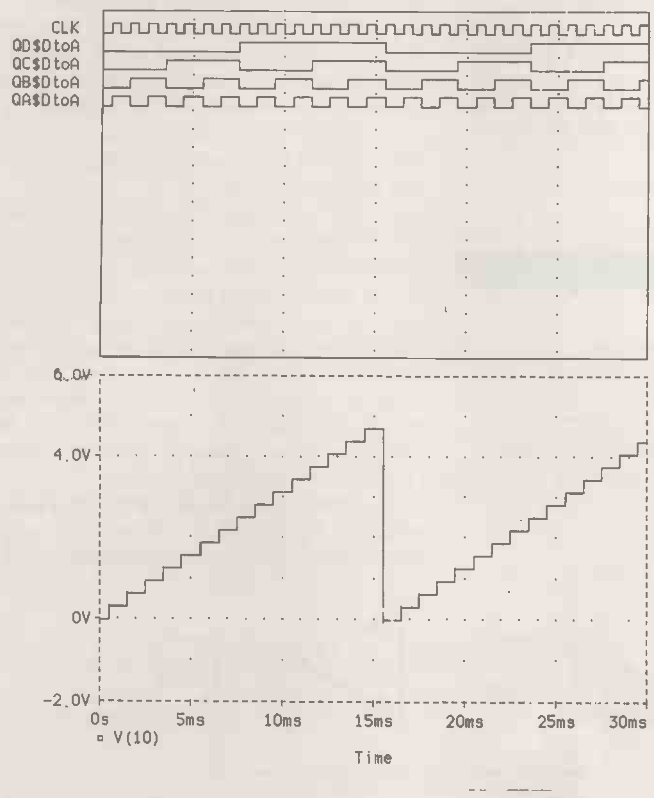

Fig. 4. The simulated digital and analogue signals of the circuit in Fig. 3.

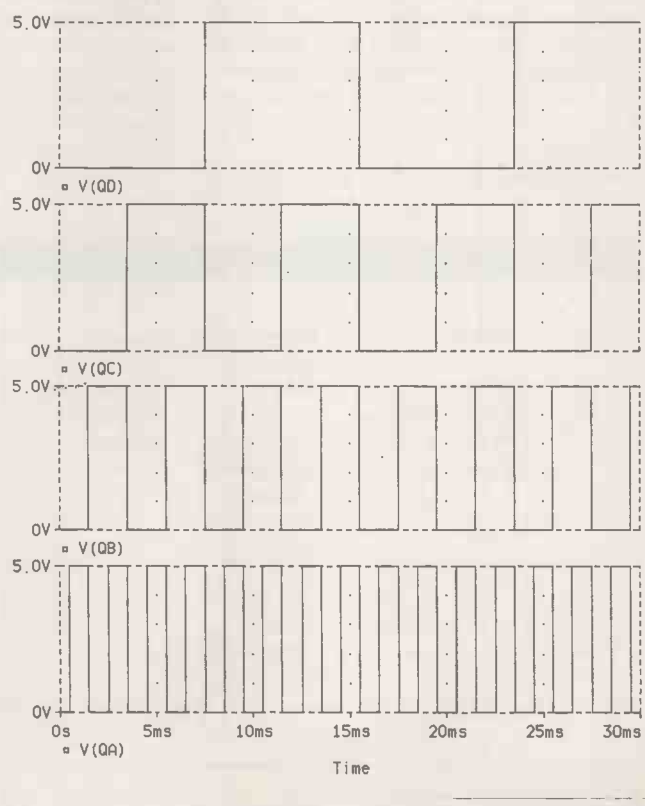

Fig. 5. Shows the waveforms of the counter outputs.

are described using passive component description statements and the voltage reference V_{ref} is described using a dc independent source statement.

Op-amps are modelled in *PSpice* using X statements. In this example it is assumed that the *TL082* op-amp is used with ±15V power supplies. The model of the *TL082* device is obtained from the 'linear.lib' *PSpice* library. Switches S_{1-8} are voltage controlled and are modelled as follows. First the input, output, control nodes and model name of the switch are described using an S statement.

For example the input and output of the switch S_1 are connected to nodes 2 and 0 respectively, while the control is connected to nodes 'QDBAR' with respect to ground. *PSpice* allows you to express nodes as numbers and/or names. For example, the control node of S_1 has been given the name 'QDBAR', which has been chosen arbitrarily.

Attributes of a switch are defined using a .MODEL statement giving the optional parameters of the switch model. The model parameters are: on and off resistance, and the control voltage for on and off switch state. In this example, all switches have been modelled using the model name 'SW1' which has all its parameters set to their model default values.

Now consider the description of the digital parts of the circuit. *PSpice A/D* has an extensive digital models library including the *74xx* ttl series and the *4000* cmos series. The library also has models of data converters and memory devices.

PSpice models digital devices using X statements. For example, the *74HC161* counter is defined by the X2 statement. To be compatible with practical digital devices, *PSpice* expresses the device nodes using names. The counter output nodes, for example, have been assigned the names QA QB QC QD, as shown in the X2 statement. Note that the parameters $D_HI and $D_LO in the statement represent a digital one and zero respectively. Finally, the inverters are defined using the X3,X4, X5 and X6 statements.

Listing 1. PSpice netlist of mixed-mode ramp generator, Fig. 3.

```
Ramp waveform generator, Fig. 3; comment line
*
* analog parts
R1 1 2 20K
R2 1 3 10K
R3 3 4 20K
R4 3 5 10K
R5 5 6 20K
R6 5 7 10K
R7 7 8 20K
R8 7 0 20K
R9 9 10 10K ; resistors
Vref 1 0 -5V ; reference voltage source
*
X1 0 9 50 51 10 TL082 ; op-amp description
Vcc 50 0 15V ; positive power supply
Vee 51 0 -15V ; negative power supply
.LIB c:\msim61\lib\linear.lib ; op-amp library
*
S1 2 0 QDBAR 0 SW1 ; voltage controlled switch
S2 2 9 QD 0 SW1
S3 4 0 QCBAR 0 SW1
S4 4 9 QC 0 SW1
S5 6 0 QBBAR 0 SW1
S6 6 9 QB 0 SW1
S7 8 0 QABAR 0 SW1
S8 8 9 QA 0 SW1
.MODEL SW1 VSWITCH [RON=1, ROFF=10M, Von=5V, Voff=0v] ; switch model
*
* digital parts
X2 CLK $D_HI $D_HI $D_HI $D_HI $D_LO $D_LO $D_LO $D_LO
+ QA QB QC QD RCO 74HC161 ; 4-bit counter
*
X3 QD QDBAR 74HC04 ; inverter
X4 QC QCBAR 74HC04
X5 QB QBBAR 74HC04
X6 QA QABAR 74HC04
.LIB c:\msim61\lib\74HC.lib ; digital devices library
.LIB c:\msim61\lib\dig_io.lib ; AtoD & DtoA subcircuits library
.OPTIONS DIGINITSTATE=0 ; clear digital devices
*
. U1 STIM (1,1) $D_DPWR $D_DGND CLK IO_STM TIMESTEP 0.5ms
+ 0c 0
+ label=loop
+ 1c 1
+ 2c 0
+ 3c goto loop -1 times ; 1kHz clock
*
.TRAN 0.02ms 30ms 0m 0.02m ; transient analysis range
*
.PROBE ; graphic outputs
*
.END ; end of netlist
```

Simulating input/output

Having described the circuit, the next step is to define the circuit input(s), desired analysis type, and how to display the simulation output results. Clock signals are defined using the U statement as shown in the listing. It has been assumed that the counter clock is 1kHz, or 1ms period. The parameter STIM in the statement is the *PSpice* symbol for the stimulus generator. Statement (1 1) defines one signal of binary format[2]. Also, the parameters $D_DPWR and $D_DGND represent digital power supply and ground nodes respectively.

To simulate the output voltage of the amplifier as a function of time, a transient analysis is required. This type of analysis is specified using a .TRAN statement. The netlist shows the transient analysis is performed over a period of 30ms.

The .PROBE command generates a data file for viewing the simulation results graphically. **Figure 4** shows the simulated digital and analogue signals of the circuit. The digital signals are the clock and the counter outputs, while the analogue signal is the amplifier output voltage. Note that the digital signals are expressed in terms of logic values (0 and 1), while the analogue signal is described in terms of voltage levels.

A number of interface nodes in the circuit of Fig. 3 occur when the counter digital outputs QD QC... and the inverter outputs QDBAR QCBAR... drive the control inputs of the analogue switches S_1, S_2.... In this case *PSpice* automatically breaks these nodes into purely analogue nodes using digital/analogue interface subcircuits as mentioned earlier. **Figure 5** shows the waveforms of the counter outputs. Note how *PSpice* changes the output from digital states 0, 1 (top waveforms, Fig. 4) into analogue voltages 0, 5V. ■

References

1. MicroSim Corporation, Pspice A/D, 20 Fairbanks, Irvine, California 92718.
2. Al-Hashimi, B, The Art of Simulation Using Pspice: Analog and Digital, CRC Press, ISBN 0849378958.
3. Horowitz, P, and Hill, W., The Art of Electronics, Cambridge University press, 1st edition, pp. 411, 1980.

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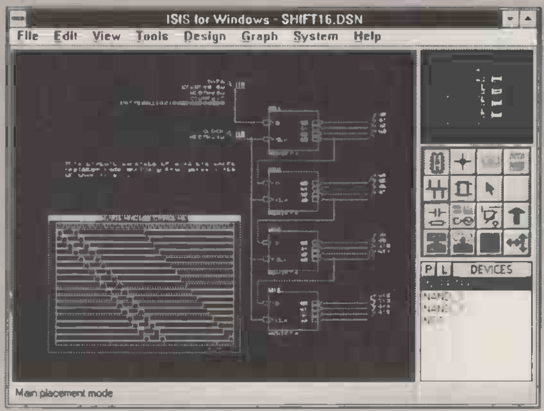

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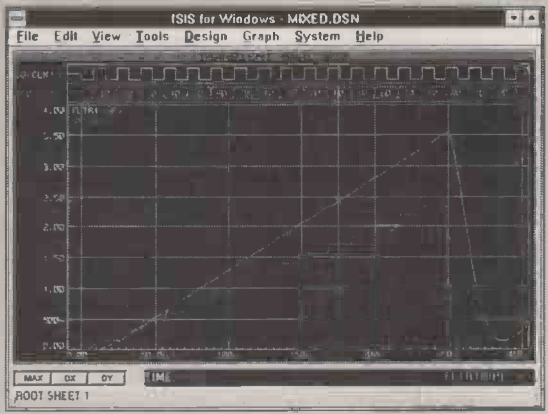

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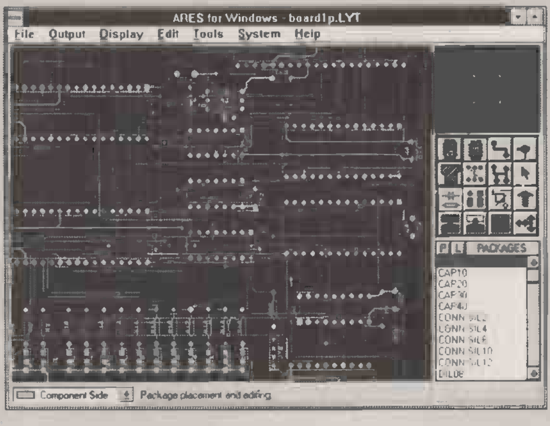
- Partitioned simulation of large designs with multiple analogue & digital sections.
- Graphs displayed directly on the schematic.



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High-speed a-to-d. *SPT7730* and *SPT7830* are two 3.3/5V 3Msample/s serial analogue-to-digital converters in 8-pin small-outline packages, recently introduced by Signal Processing Technology.The *7730* is an 8-bit, serial-output device, sampling at 3Msample/s, *7830* being a 10-bit type with a sample rate of 2.4Msample/s. Both are cmos devices with on-chip s/h and provide a reference settling time of 90ns. Signal Processing Technology. Tel., 01932 254904; fax, 01932 254903.

Discrete active devices

1GHz transistor. Motorola has the *MRF5811LT1* rf n-p-n silicon transistor for low-power application at frequencies up to 1GHz. Dc gain on a 300μs pulse is 50-200 and f_T typically 5GHz, collector/base capacitance at 10V and 1MHz being about 2pF. Noise figure at 50mA, 10V and 500MHz is 2dB. Motorola Semiconducteurs sa. Tel., 00 33 61 199981; fax, 00 33 61 199565.

Linear integrated circuits

Catv amplifier. For broadband, low-distortion application – and particularly for catv use – Motorola's *MNN424B* feedforward amplifier consists of two hybrid ampliers, couplers and delay lines in one package. It is a 750MHz maximum, 110-channel, 24dB power gain device, giving at least 20dB improvement over conventional catv amplifiers. Gain flatness is ±0.3dB up to 750MHz. Motorola Inc. Tel., 001 602 244-3831; fax, 001 602 244-6002.

Memory chips

Notebook dram. Mitsubishi's 3.3V or 5V dram *MelCard* comes in 4, 8, 16 and 32Mbyte form and is suitable for Toshiba, IBM, Compaq and some other notebook computers. The cards have 88-pin connectors and are compatible with JEIDA and JEDEC. Power consumption of the 3.3V type is 930mW. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Microprocessors and controllers

Very low-cost controller. Toshiba's new member of its *TLCS-90* family of 8-bit microcontrollers is the *TMP90CM38*, which is much cheaper than its *TMP90CM36* pin-compatible stablemate, being a general-purpose device without specialised peripherals and timing. The *TLCS* core remains, providing a 163-instruction set, 16-bit arithmetic, minimum instruction time of 250ns at a 16MHz clock speed and dma functioning. Toshiba Electronics UK Ltd. Tel., 01276 694600; fax, 01276 694800.

Pentium replacement. Announced as a plug-in replacement for the Pentium, AMD's *AMD5$_K$86* chips, in P75 and P90 form, give the performance of the relevant Pentium chips according to the Ziff-Davis Winstone 96 P-rating tests and have been licensed to carry the Windows 95 logo. Advanced Micro Devices (UK) Ltd. Tel., 01483 740440; fax, 01483 756196.

Starter kit. Texas offers the *TMS370* 8-bit microcontroller starter kit, which includes eprom/eeprom programming board and all software and literature. The kit may be connected to COM1 or COM2 pc ports by way of a standard RS-232C lead. Power needed is 5V at 500mA. Farnell Components Ltd. Tel., 0113 2636311; fax, 0113 2633411.

Mixed-signal ICs

Quad codec. AKM's *AK2304A* combines four conventional voice codecs in one 44-pin package and complies with CCITT G711/2 and AT&T D3/4 requirements. It is a selectable A-law/μ-law device operating from one 5V supply and dissipating about one-third the power of four codecs. There are internal op-amps for gain adjustment and anti-aliasing and a 2.048Mb/s pcm highway interface. The device can be used in ST-bus or GCI interface systems and muting is done by toggling mute control pins. DIP International Ltd. Tel., 01223 462244; fax, 01223 467316.

Motors and drivers

3hp servo amplifier. Copley Controls introduces the *Model 5231* brushless servo amplifier which puts out ±30A – ±15A continuous – to provide rapid acceleration and regenerative braking for motors up to 3.4hp. It operates at 25kHz, has a 3kHz bandwidth and copes with motors presenting a load of 0.2-40mH. Supply is 24-180Vdc, from which a four-quadrant supply is developed, and a current-sensing circuit gives an analogue output for monitoring. Two different boards are available to allow the amplifier to take brushless tachos, motor hall sensors or digital encoders to develop velocity feedback. Copley Controls. Tel., 001 617 329 8200; fax, 001 617 329 4055.

Optical devices

Photo-interrupter. Isocom's *ISTS802* optical interrrupter switch has a 5mm slot and a 0.5mm aperture for the light for increased sensing accuracy. Switching time when the beam is interrupted is 3μs. A number of case styles is offered and Isocom says it can design styles to suit requirements. Isocom Components Ltd. Tel., 01429 863609; fax, 01429 863581.

Lens holders. Melles Griot has a new range of bench lens holders for experimental work, which are fitted with easily distinguishable locking knobs and adjuster knobs. Not much more to say, really, except that the holders hold firmly and won't move until you move them. Melles Griot Ltd. Tel., 01223 420071; fax, 01223 425310.

Lasers. A range of visible and infrared lasers is available from UV-Tec in wavelengths of 635, 650, 660 and 670nm at 5mW, near infrared wavelengths of 780, 830 at up to 30mW and 808nm at 5mW. There is also a self-contained lab. version with an emission indicator and power switch. UV-Tec Ltd. Tel., 01252 844880; fax, 01252 844885.

Surface-mount darlington. The Zetex *FZT603* Darlington, an E-line device and SOT223 device, has a minimum h_{FE} figure of 5k at 500mA and 5V, V_{CBO} and V_{CE} of 100 and 80 and saturation voltage of 0.79V for 0.25A collector current and 0.25mA base current. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

PASSIVE

Passive components

Chip thermistors. Taiyo Yuden has ntc chip thermistors rated at 63mW in size 0603 and made in values from 220Ω to 150kΩ, although lower values can be supplied to order. The multilayer technique in use provides much less change in resistance than conventional glass-coated types.Thermal time is under 5s and heat dissipation constant 1-2.5mV/°C. Taiyo Yuden UK. Tel., 01494 464642; fax, 01494 474743.

Surface-mounted electrolytics. Panasonic's *VS Series* of aluminium, s-m electrolytic capacitors, which are all 5.5mm high, covers the range 22μF-220μF, 4V to 0.1μF-10μF, 50V. The *VA series* 50V types go up to 47μF and the 6.3V series has values of 1000μF, maximum ripple of 700mA at 120Hz and operating temperature of 85°C. These are wave-solderable. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Audio products

Multimedia audio recording. AKM's *AK4531* is a mixer codec for pc-based recording applications, having a two-channel, 16-bit audio codec and a two-channel, 18-bit digital-to-analogue converter, both with an

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86dB dynamic range. It has five-channel stereo and three-channel mono playback mixers. Sampling rates are 4-50kHz for variable audio bandwidth and input can be down to –60dB. DIP International Ltd. Tel., 01223 462244; fax, 01223 467316.

Connectors and cabling

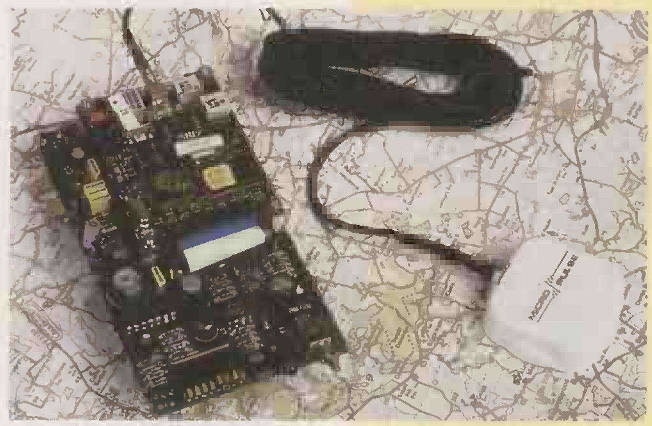
Miniature connectors. Amp *Micro-MaTch* connectors have a contact spacing of 1.27mm, the range including board and wire connectors to allow a variety of wire-to-board and interboard connections. Versions in the range are somewhat improbable-sounding but, to quote, are "female-on-board, top entry, side entry and surface-mount; male-on-board; male-on-wire; and paddle board connector". Contact springs are in the board connector rather than, as usual, in the cable connector. In the cable connector is a simple pin with either insulation-displacement section or a kinked solder leg, so separating and optimising the contact force generation and termination requirements. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Relay sockets. Inelco has a range of DIN sockets and bases for relays, mountable on DIN rails, printed boards and chassis and all having finger protection and low flammability material. Examples are a screw base for the two-pole 4.7/5mm blade plug-in relays, which can be surface mounted or clipped to a 35mm DIN rail, rated at 240V ac, 10A; and a 14-pin base for 4-pco miniature relays, timers and controllers rated at 240V ac, 5A. Inelco Ltd. Tel., 01734 810799; fax, 01734 810844.

Chip sockets. Robinson Nugent's *TSOP* and *QFP* low-profile surface-mounted sockets are meant for ram, rom and other lsi devices where replacement may be necessary. *TSOP* types have 28, 32 or 40 pins at lead spacings of 0.5, 0.55 and 1.27mm, *QFP* models are in 64 and 80-pin styles on a spacing of 0.8mm. Contacts are rated at 0.1A for the *TSOP* and 0.2A; breakdown 500V ac, insulation 1GΩ, contact resistance 60mΩ for the *TSOP* and 50mΩ. Robinson Nugent (Europe) Ltd. Tel., 01256 842626; fax, 01256 842673.

Test points. Glass-beaded, board-mounted test points by William Hughes consist of a colour-coded bead and phosphor bronze, tinned tag, with 1.3-2.03mm diameter loops for probe connection or to take other components; so raising them above the board surface. The tags are so shaped to avoid damage to through-hole plating and to keep the test points in position when the board is being flow soldered. William Hughes Ltd. Tel., 01963 363377; fax, 01963 363640.

General-purpose dso range. Goulds's *600 Series* is a new range of digital storage oscilloscopes for general use. Three models have 100Msample/s sampling, 50,000 words of memory per channel, a colour display, built-in floppy drive, auto measurement and IEEE-488.2 and RS232 interfaces. Model *640* is a 150MHz bandwidth instrument which can acquire 'difficult' signals; *650* has a 400MHz bandwidth and is for showing fine detail in wide band signals and *680* has 12-bit resolution and 150MHz bandwidth, with vertical zoom to give a 32 times expansion, or 62.5μV to 40V per division. *650* and *680* offer the option of a thermal plotter. Gould Instrument Systems Ltd. Tel., 0181-500 1000; fax, 0181-501 0116.



Displays

Lcd/tft panel driver. IMS has a new multi-display video controller card, the *PCA-6653*, which simultaneously controls SVGA crt displays and flat-panel tft, dstn, mono lcd or electroluminescent types. It is register and bios-compatible with the IBM VGA standard and has a Windows graphics accelerator. There is on-board memory and a 256K by 16 dram socket to take an optional frame buffer. Integrated Measurement Systems Ltd. Tel., 01703 771143; fax, 01703 704301.

Hardware

Collet knobs. Ritel collet knobs are available in diameters from 8mm to 45mm in polyamide material and all offer a choice of style, colour and matt or gloss finish. Collets are ready assembled and fit a range of shaft sizes without the use of special tools. Accessories include shaped or flat caps with a variety of markings, pointers and arrow dials. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Enclosure framework. Widney Dorlec would like to point out that the *20/30 Series* enclosure framework system, introduced in 1951, is still around. In fact, the company is currently tooling for more components to add to the 79 corner castings and 47 extrusion profiles already available. For the benefit of anyone who has been on Saturn for some decades, it is a set of extruded aluminium sections and corner shapes which are screwed together with concealed bolts to make a smooth cabinet, having been cut to size with a hacksaw. Widney Enclosures Ltd. Tel., 0121-327 5500; fax, 0121-328 2466.

Test and measurement

Emc and flicker meter. From Seaward comes the *Orb* harmonics and flicker meter, to test single-phase equipment rated at up to 16A to EMC Directive standards. It carries out Class A, B, C and D harmonic testing using Fourier analysis and flicker measurements are taken at up to 10min and 2h respectively. The instrument is pc-controlled and is provided with a windows-based package to give features such as limit lines, pass/fail indication and many data display options. Test results are transferable to final report documents. Seaward Electronic Ltd. Tel., 0191-586 3511; fax, 0191-586 0227.

Infrared thermometer. Calex Instrumentation introduces the *Convir Close Focus* series of portable infra-red thermometers, which measure the temperature of objects down to 3mm diameter. Resolution is 1°C to within ±1%, with a response time of 350ms. The instrument is strong enough for factory floor use. Calex Electronics Ltd. Tel., 01525 853800; fax, 01525 851319.

Real-time/storage oscilloscope. *VC-6555* by Hitachi is a 100Msample/s (two channels) and 100MHz bandwidth oscilloscope, with 8Kword capacity for a single channel, delaying sweep and a counter. One-

Navigation systems

GPS starter pack. From TDC comes a global positioning system starter pack, which is based on the Rockwell *Microtracker LP* receiver and which also contains a TDC evaluation board, magnetic car antenna, mains power unit, cable, batteries, manual and software. The TDC board provides the power and serial level conversion for the *Microtracker* and conditioned power for the antenna, output being over an RS232 port to a pc. Accuracy is within 5m, 95% of the time. If Autoroute Express, now swallowed up by Microsoft, is also bought from TDC, a GPS driver is supplied. Telecom Design Communications Ltd. Tel., 01256 332800; fax, 01256 332810.

shot and intermittent events are easily captured and a pre-trigger function shows the leading edge of a triggering waveform. Averaging reduces noise and sweep rate is automatically adjusted for the input frequency. Output is available for hard copy and, via the RS232 interface, for a pc. Hitachi Denshi (UK) Ltd. Tel., 0181-202 4311; fax, 0181-202 2451.

GPS station clock. Nothing to do with BR, the *8820A GPS Station Clock*, available from Steatite, is a time generator whose outputs are synchronised to within 100ns of UTC. It automatically tracks up to six GPS satellites, disciplines its own crystal or rubidium low-noise oscillator and synchronises its outputs to universal time, automatically accounting for leap years and seconds. Several time and frequency outputs are provided, as are two RS232 ports and an optional IEEE-488 port. Steatite Insulations Ltd. Tel., 0121-643 6888; fax, 0121-643 2011.

Measuring amplifier. HBM has a small digital amplifier, for the measurement of mechanical quantities, that is for use in laboratory and mobile application. *Scout55* operates at 4.8kHz, being connected by the 6-wire technique to strain gauges, half and full bridge inductive transducers, piezoresistive and potentiometric transducers and linear variable differential transformers. It has a membrane keyboard, protected for hard use, and a ten-digit readout; its RS232C interface allows pc control. HBM United Kingdom Ltd. Tel., 0181-420 7170; fax, 0181-420 7336.

Lout-proof keypad. Numeric keypads in the C & K *4800 Series* are sealed and gasketed to IP66 and have a 2mm stainless steel faceplate bolted to the polycarbonate body that holds the membrane, so that the average grunt would have a hard time doing them much permanent damage. The keys have click feel and 0.05-50mA, 1.5-30V dc ratings. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Rso. Which is to say, real-time and storage oscilloscope, Hitachi Denshi's family of which is now being completed by the introduction of the *VC-6645*. This instrument is a 100Msample/s, 25msample/s (four-channel), 100MHz, 4Kword (single-channel) type with delayed sweep and a 100MHz frequency counter. A standard RS-232 interface allows stored waveforms to be transferrred to a computer using Hitachi *HIMES* software and the memory contents are held for up to 10 days when power is switched off. Hitachi Denshi (UK) Ltd. Tel., 0181-202 4311; fax, 0181-202 2451.

Low-resistance measurement. Used in conjunction with one's own digital multimeter, the Sutronics *Millo-Test 200* enables the measurement of resistance on a most sensitive range of 200mΩ. Inherent accuracy of the *Millo-Test* is typically 0.1%, but final accuracy depends on the dvm in use. A four-terminal bridge method is used, providing a guaranteed 0.2% accuracy at 20°C for the instrument itself, temperature coefficient being 0.02%/°C from 0°C to 40°C; best accuracy is at 20°C. Test current on all but the 20Ω range is 20mA. Sutronics. Tel./fax, 01929 426400.

Literature

Siemens semiconductors. Technical data on cd-rom from Siemens provides data sheets, s-parameters, curves and signal charts, together with the Microelectronic training centre, sales information, data for circuit simulation, technical articles and more. The disk is available for dos or Windows and can be installed in networks. There are also files for component comparison and a data retrieval system. BFI IBEXSA Electronics Ltd. Tel., 01622 882467; fax, 01622 882469.

Instrument hire. Livingston Rental, formerly Livingston Hire, has published its first catalogue under the new name. It contains much new equipment and a number of new services in the instrumentation field. The catalogue is free. Livingston Rental Ltd. Tel., 0181-943 5151; fax, 0181-977 6431.

Data communications. Dataforth Corporation has issued a new catalogue of Industrial Data Communications Products which, in 50pp, provides full specifications, applications and installation data on modems, optical-fibre multiplexers and rack-mounted modems. Impulse Corporation Ltd. Tel., 01543 466552; fax, 01543 466553.

Thurlby Thandar. TTi has a new free catalogue of electronic test gear, which is all developed and made in the UK. New this time is the *1705* a 4.5-digit, dual-display multimeter with an RS-232 interface, true-rms ac measurement, frequency measurement and an optional GPIB interface. There is also a range of counters that handle up to 1.3GHz and a number of instruments for emc testing. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

Power supplies. From Computer Products, the *1996-7 Power Supply Product Handbook* fully describes the company's range of ac/dc supplies, dc-dc converters and dc/ac ring generators, over 1200 in all, 800 of them new this time. Also on offer are three free technical guides on thermal management, safety regulations and emc and principles of power conversion. E-mail on jackie.day@cpipce.cpi.sprint.com. Computer Products, Power Conversion Ltd. Tel., 01494 883113; fax, 01494 883419.

Farnell Components. You can order Farnell's new catalogue and obtain data on the Internet (http://www.farnell.co.uk) or, if you suffer from technofear, the 'phone from 8am to 8pm. The 50,000 products, 6000 of them new ones, should satisfy most people's needs, since it includes everything from ordinary passive and active components to network and datacom equipment and top-end instrumentation. Farnell Components Ltd. Tel., 0113 2636311; fax, 0113 2633411.

Printers and controllers

Small print heads. Mitsubishi's *WH Series* 24V dc thermal print heads take the form of a small, flexible printed circuit with a connector, and are intended for incorporation into low-cost mini-printers. They are based on a thick-film process, cmos chips providing shift register, latch and switching functions. The heads are 5mm high and are in the form of a hard ic moulding, requiring no other cover, since the drive ics are epoxy coated. Print widths are 48mm, 72mm and 96mm in the three types available, with resolution of 8dot/mm and selectable speed of 3 or 10ms/line. Mitsubishi Electric UK Ltd. Tel., 01707 276100; fax, 01707 278692.

Production equipment

Workstations. Robert Bosch's *ESD* range of workplaces are electrostatically discharged to reduce the number of ics blown by voltages in excess of 100V, which can easily be developed by a worker who shuffles about a bit too much. The workplaces are designed to suit customers' requirements in width and height and are provided with chairs, component containers, trolleys, shelves and a number of other features to reduce not only the shuffle factor but also injuries such as RSI and tendonitis. Robert Bosch Ltd. Tel., 01895 834466; fax, 01895 838548.

Power supplies

Dc-to-ac converters. *PROwatt* inverters, which are CE-approved, convert battery power to 230Vac to allow mains equipment to be run from 12-24Vdc, these new versions conforming to interference standards. The *150i* and *250i* units are in an aluminium case and connect to a cigar-lighter socket or a terminal strip, providing the 230Vac via an IEC 320 socket on the case. The units cope with difficult loads, such as low-energy light bulbs, and overheating and overload protection is provided. Low battery voltage gives rise to an audible alarm and switch-off. *PROwatt* prices start at £49.95. Merlin Equipment. Tel., 01491 824333; fax, 01491 824466.

Adhesive printing. Loctite *Varidot* is a new stencil system which prints different heights of surface-mounting adhesive to suit different components in one pass of the squeegee. This is brought about by the use of a flexible stencil providing off-contact printing, which also avoids contaminating the underside of the stencil and therefore cleaning, except when the stencil is changed. Printed dot diameters can be as small as 0.3mm or up to 1.6mm, varying in height from 50microns to 0.6mm. Loctite UK Ltd. Tel., 01707 821000; fax, 01707 821200.

Transformer kits. For those occasions when no available transformer known to man will do the job, Electrospeed can now offer kits to make your own. Kits consist of a double bobbin section, half of it already wound with two independent 115V primaries, a pair of bobbin half shrouds, E and I laminations, end caps and all the other bits, including wire in 12 sizes from 0.2mm to 1.5mm diameter. Four kits cope with ratings of 20, 50, 100 and 200VA. There is a standard turns/V figure for each to give the wanted output voltage and the kits have full instructions and working examples. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

Plug-in switchers. Relec's *Mascot 9000* series of switched-mode power supplies are cased units plugging straight into a mains outlet and giving 10-40W outputs of 5-24Vdc. Line stabilisation is 0.1% and load regulation below 3% for all models. Output connection is a 2m cord with one of a selection of single or multi-headed jack plugs. Reflec Electronics Ltd. Tel., 01962 863141; fax, 01962 855987.

25W and 40W switching psus. XP announces the *NAN 25* and *NAN 40* low-cost, universal ac input switchers, which use a fixed switching frequency to allow them to meet EN55022 emi specifications. The range of modules provides outputs from 5V to 48V in singles and various arrangements of 5V, 12V and 15V in duals and triples. Input is universal 90-264Vac, overvoltage and overcurrent protection is present and the units measure 5 by 3 by 1.2in. XP plc. Tel., 01734 845515; fax, 01734 843423.

PCMCIA card. Amplicon Liveline's *PCM DAS08* and *DAS16* PCMCIA data acquisition cards fit type II and type III expansion slots in portable computers. Suppied with card-socket services and universal driver software, the cards have have a 12-bit analogue input and automatic configuration on insertion. *DAS 08* takes eight bipolar, 12-bit analogue, ±5V inputs, gives digital i/o and samples at 3.12, 6.25, 12.5 and 25kHz, selectable in software, while *DAS16* provides 16 bipolar/unipolar inputs from ±10V to ±1.25V and from 0-10V to 0-1.25V, with eight digital i/o and three 16-bit counters. It also has a high-speed driver for the Labtech Notebook Pro. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Network ups. *MaxiMiser* from Galatrek is a range of single and three-phase uninterruptible power supplies covering the 5-15kVA output band and intended for large lans, mid-range systems, servers and data processing centres. Their non-volatile memories store up to 5000 parameters to give a history of ups and mains activity, the result being passed by RS232 or a front-panel lcd. Regular battery tests are run automatically or when a panel button initiates a test and the units adjust their chargers to suit the battery temperature. Galatrek International Ltd. Tel., 01492 640311; fax, 01492 641828.

Radio communications products

Satcom frequency converters. Anglia Announces the *Zeta 6160* range of frequency converters to convert communications signals from and to the microwave bands used by satellites. *Zeta 6163* converts 70, 140 or 700MHz ifs to an intermediate C-band signal tunable between 5850 and 6425MHz, with phase noise at 85dBc/Hz for 10Hz offset, and is therefore usable as a standalone Intelsat-C converter. This output will drive the *6161* band-selectable block up-converter for conversion to X-band or Ku-band for DSCIII and Intelsat. Reverse conversion is carried out by the *6160* and *6162* units. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

Protection devices

SM transient suppressors. Semitron *SMBJ* series transient voltage suppressors are surface-mounted devices rated at 600W and providing picosecond turn-on and low on impedance. With ratings of 5V to 170V, in unidirectional and bidirectional form, peak transient current in avalanche mode is 2.2A to 62.5A for 170V and 5V devices respectively, while in the forward direction, the devices withstand 100A for 8.3ms. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

PC radio receiver card. Rosetta Laboratories of Australia make the *WinRadio* radio receiver card and software for the pc. The card plugs into a slot in the motherboard and contains a processor-controlled wideband receiver with antenna, speaker and headphone connectors. It covers the 500kHz-1.3GHz range in tuning steps from 1kHz to 1MHz and handles am, fm-w, fm-n and ssb at 1μV sensitivity. Being Windows-based, a 'front panel' is displayed on-screen to give full control in the normal way. A scanning facility is provided and there is a database of over 300,000 frequencies, which can be extended by the user. Screening has received much attention to allow the receiver to operate inside the pc. Lowe Electronics Ltd. Tel., 01629 580800; fax, 01629 580020.

Switches and relays

Time-delay relays. Matsushita offers the *TR/TS* ultraminiature time-delay relays, which will switch 10^{-10} to 1kVA on each of four separate contacts arranged in various forms of open and closed. Each *TS* contact will carry 5A at 250V, although the relays measure only 34 by 34 by 10.8mm. Both are available for conventional on/off delay timing and, for off delay, no extra power supply is needed. Using either an internal trimmer or an external pot., timing is adjustable from 0.1 to 1000s. The relays are available in 5, 12 or 24Vdc operation. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Switch lens caps. EAO-Highland offers a range of lens caps to make its *EAO Series 96* family of illuminated, push-button switches look better. The lenses are rounded and come in black(?), red, green, grey, bright orange and blue. There are versions with recesses for one or two leds and for momentary or maintained operation. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Sealed keyboard. Announced by Fairchild is the *KBM Series* of metal-cased keyboards sealed to IP65 standard and provided with a tracker ball. They come in a variety of forms, for both desk-top use and to mount vertically in a panel and are compatible with IBM AT or PS/2, the serial output from the tracker ball suiting Windows applications. Keys have a positive feel with 1.4mm movement and the front panel is chemical resistant. Fairchild Ltd. Tel., 01703 211789; fax, 01703 211678.

Automotive relays. Han-Kuk's *HR-AMR* series of board-mounted relays for cars provide 40-60A switching in a 26 by 22 by 22mm package, sealed or open, accepting 6-24Vdc. Life is said to be in excess of 10^7 operations. Inelco Ltd. Tel., 01734 810799; fax, 01734 810844.

Transducers and sensors

Shaft encoder. *Digipots* are simple, self-contained shaft encoders, designed for use in x/y detection, motor speed monitoring, pick-and-place of components and many other areas. They are non-contacting panel-mounted types, producing a two-channel, quadrature digital output proportional to rotation at speeds up to 10,000rev/min. Power needed is under 40mA at 5V. Line counts on the internal disc are from 96 to 2048 per revolution, with an optional index. Accessories include line-driver cards and power supplies. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Vision systems

Graphics accelerator. Ark Logic offers the *ARK2000MT* 64-bit graphics and video acclerator, which supports the graphics functions such as BITBLT, line draw, pattern-BLT, colour expansion and raster-ops used by graphics user interfaces. Resolutions are from 640 by 480 to 1600 by 1200 and colour depths 4-24bits/pixel, depending on the amount of dram installed and the resolution. It will accept YUV video from a software decompression utility and perform colour space conversion and scaling of the video image to full screen size, interfacing with both PCI and VESA local bus motherboards. The board comes with a set of drivers. Amega Technology Ltd. Tel., 01256 330301; fax, 01256 330302.

COMPUTER

Computer board-level products

3U single-card pc. On a single 3U VME bus card, Ovation's *VME 486 PC* supports all standard pc i/o functions such as keyboard interface, two serial i/o ports, Centronics/parallel i/o interface, floppy and hard disk interfaces and a high-resolution VGA display. An optional module allows up to 16Mbyte of dram in simms, Ethernet connection and dual-port static ram expansion to 1Mbyte. Ovation Systems Ltd. Tel., 01844 279638.

Single-board computer. *Apex II* from Blue Chip is a single-board computer for industrial and embedded applications, having processor, video and peripherals on one 5V board. It takes 486SX up to P24T processors and provides a 16Mbyte maximum dram memory in 72-pin simm form. There is 1Mbyte of flash memory to give solid-state disk storage, and two further sockets for more of the same. Local bus SVGA video control has 512Kbyte of vram to give 640 by 480 colour lcd. Blue Chip Technology. Tel., 01244 520222; fax, 01244 531043.

Data acquisition

Modular, PC-compatible system. Yokogawa's *DARWIN*, a modular family of data acquisition instruments, will compose a complete data-logging system from a range of input measurement and scanning modules, output modules such as computer interfaces and alarms, and hard-copy recording. Each system may be specified as a stand-alone unit with up to 40 channels or as an expandable system with from 10 to 300 channels. The standard software handles data logging and configuration, while an enhanced package is available that provides trends, bar graphs, panel-meter-type display and alarms. Built-in maths functions allow for signal processing before measurements are passed to the pc. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

Development and evaluation

Thermal development. Redpoint Thermalloy has a design kit containing a selection of active and passive heatsinks, materials and accessories, with data, to help with the thermal management of microprocessor-based designs. The kit includes the Thermalloy Cooling Module, which is a pin-fin type with a fan, in 5V and 12V versions. It all comes in a carrying case. Redpoint Thermalloy Ltd. Tel., 01793 537861; fax, 01793 615396.

Software

Emc measurement. *ESxS-K1* from Rohde & Schwarz is a Windows-based package for emc measurement in small and medium-sized companies. It supports R & S emi test receivers and eases the user's task by providing dialogues and masks for entering data. Features include single-keystroke measurement, graphic display of test results and scan data, comparison of limit lines with peak search function and average-value detection. Rohde & Schwarz UK Ltd. Tel., 01252 811377; fax, 01252 811447.

High-level language debugger. Noral Micrologics offers the *Flex* universal, real-time embedded systems debugger for Windows, which incorporates an integrated macro language and editor for 8-bit, 16-bit and 32-bit applications. It operates independently of hardware providing the information from the embedded system and can be used with in-circuit emulators and background debug mode hardware, rom monitors and simulators for use in the future. It is also independent of file formats. Noral Micrologics Ltd. Tel., 01254 682092; fax, 01254 680847.

Industrial control. From PC Soft International comes *Wizcon 5*, a Scada package in true 32-bit Windows 95 native code. (Scada is short for 'supervisory control and data acquisition'.) It is designed for use in both stand-alone applications and in systems for manufacturing and management information, including such applications as control and supervision of processing and manufacture, building automation and public utilities. New features in v.5 are on-line diagnosis and de-bugging and cluster libraries of animations for many processes. The company offers the package with no extras, all options being included. PC Soft International. Tel., 01233 503838; fax, 01233 513687. ■

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CIRCLE NO. 138 ON REPLY CARD

Putting the **power** back in

In the second extract from his book *Simplified design of micropower and battery circuits,* John Lenk shows how to apply the *MAX712/713* and other ICs in a wide variety of charging circuits.

If you read Part I of this article in the March issue, you should have a good understanding of how the *MAX712* and *713* work. These are highly integrated charger ICs specifically designed for use with NiCd and NiMH cells.

Here is a basic simplified design procedure for using these ICs – and others – in practical circuits. The following steps assume that the maximum power dissipation is not exceeded in your application, that the charge current does not exceed 600mA, and that the battery stack has 11 cells or fewer.

Check recommendations: Follow the battery manufacturer's recommendations for maximum charge currents, as well as charge-termination methods for the specific batteries in an application. **Table 1** provides some general guidelines. When the charge rate is greater than 2C, use both temperature and voltage-slope/time. With charge rates below C/2, use the *MAX712* for NiMH batteries. Use the *MAX713* for all NiCd applications.

Decide on a charge rate: A charge rate of C/3 (where C is the battery capacity) charges the battery in about 3h. Current in milliamps required to charge at this rate is calculated as:

I_{FAST}=(capacity of battery in mAh)/(charge time in hours)

Depending on the battery, charging efficiency can be as low as 80%, so a C/3 fast-charge could take 3h 45min. This has nothing to do with the efficiency of the IC, but reflects the efficiency with which electrical energy is converted to chemical energy within the battery.

Choose an external dc power source: An example of this is a wall-cube. Minimum output voltage, including ripple, must be greater than 6V and at least 1V higher than the maximum battery voltage.

Know the power dissipation: Calculate the worst-case power dissipation of the power p-n-p transistor Tr_1 and diode D_1 in Fig. 2, "Putting the power back in, Part I" *EW*, March, pp. 223-228) in watts, using:

PD=(max wall-cube voltage, loaded–
min battery voltage)×(charge current in amps)

Make sense: If the calculated power dissipation exceeds the maximum; if the battery stack has more than 11 cells, or if the charge current exceeds 600mA, calculate R_1 and R_{SENSE} as described in Part I. Otherwise,calculate the values of R_1 (in kΩ) and R_{SENSE} (in kΩ) as follows:

R_I=(*minimum wall-cube voltage*–5V)/5mA

then,

R_{SENSE}=0.25V/(I_{FAST})

Check pin-straps: Consult **Tables 2** and **3** to determine the pin-strap settings. For example, with a battery of six cells, both PGM0 and PGM1 (pins 3, 4) should be left open. For a charge time of 90min with the charge-slope limit enabled, PGM2 and PGM3 (pins 9, 10) should be connected to REF (pin 16).

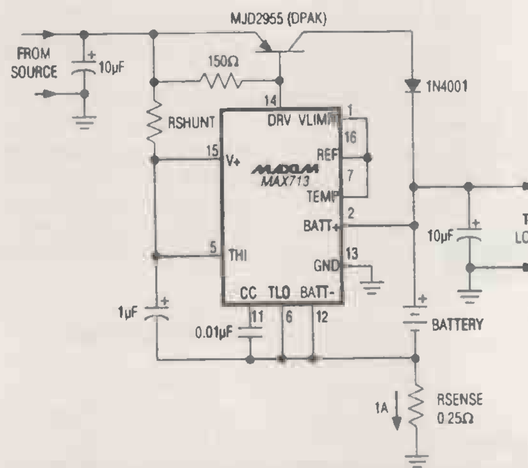

Fig. 1. NiCd/NiMH charger with step down regulator (Maxim Battery Management Circuit Collection, 1994, p. 2).

Table 1. End of charge.

Termination methods for fast-charge controllers (Maxim New Releases Data Book, 1994, p. 4-55).

Charge	NiMH cells	NiCd cells
>2C	DV/Dt and temperature Max712/3	DV/Dt and temperature MAX713
2C to C/2	DV/Dt and/or temperature Max712/3	DV/Dt and/or temperature MAX713
<C/2	DV/Dt and/or temperature Max712	DV/Dt and/or temperature MAX713

Simple fast-charger with linear-regulator

Figure 1 shows the *MAX713* connected to provide a fast-charge with linear regulation to both NiCd and NiMH batteries.

Note that Fig. 1 is similar to Fig. 2 in Part I. The major difference is that the external pass transistor in Fig. 1 is a *MJD2955* and the resistor at pin 15 (*V+*) is called R_{SHUNT} instead of R_1, as in Fig. 2, Part I.

The circuit of Fig. 1 solves two closely related problems found in powering small portable systems – firstly charging the battery and secondly switching over from battery power to ac power when an external ac-to-dc adaptor is plugged in. The *MAX713* supplies the system load current while the battery is being charged by sensing and dynamically regulating the battery current.

Using a linear regulator instead of a switch-mode circuit is a good approach for small systems: palm-top computers having low-voltage ac-to-dc adaptors and low-wattage battery packs with 5V, 9V, and 12V outputs are common examples. The linear regulator approach is also effective for battery back up in non-portable systems, such as large file servers.

The choice between linear and switch-mode is usually a matter of what is an acceptable power dissipation in the regulator pass transistor. For instance, fast-charging three 750mAh NiCd cells from 9Vdc at a 1C rate produces a worst-case dissipation of about 5W. This dissipation is too high for most hand-held applications.

The *MAX713* must be programmed for the desired number of cells and charging time. Use the pin straps, as described above, with Tables 2 and 3. The circuit will charge up to 16 cells.

Operating area of the *MAX713/MJD2955* circuit, **Fig. 2**, shows that if the input-output differential can be kept low, the operating current – i.e. charging current plus load current – can be 1A. Input voltage range is battery voltage plus 1V, up to 20V, with a 5V minimum. Supply current when not charging is 5μA maximum. Charging current is limited only by maximum power dissipation *PD*, and efficiency is battery voltage divide by source voltage multiplied by 100%.

For example, if the supply voltage is 6V, used to charge a 3V battery, efficiency is 3/6×100=50%.

Where heat-sinking is not practical, fast-charging large batteries in compact enclosures raises the problem of temperature rise. The battery-charger current source must have adequate efficiency to prevent temperature rise. This usually means some form of switch-mode current source, if the charging plus load currents – i.e. operating current – is greater than about 1A.

Fast-charger with switch-mode current source

The *MAX713* can be connected as a switch-mode regulator to provide a fast-charge for both NiCd and NiMH batteries, **Fig. 3**. The operating area of the switch-mode circuit, **Fig. 4**, shows the input voltage range is battery voltage plus 1.5V, up to 20V, with a 7V minimum. Efficiency is 80% with an input of 12V and two cells being charged at 1A. Note that the circuit of Fig. 3 is programmed for two cells, with PGM0 strapped to *V+*; PGMl open, and for a time-out of 90min, i.e. PGM2 and PGM3 strapped to RET.

Control loop for the circuit is a variable-frequency type, which senses and regulates current through the battery. Battery current is measured by the 0.08Ω resistor (R_{SENSE}), and this sense signal is compared to an

Table 2. Number of cells.

Programming the number of cells for fast-charge controllers (Maxim New Releases Data Book, 1994, p. 4-56).

No of cells	PGM1	PGM0
1	V+	V+
2	open	V+
3	REF	V+
4	BATT–	V+
5	V+	open
6	open	open
7	REF	open
8	BATT–	open
9	V+	REF
10	open	REF
11	REF	REF
12	BATT–	REF
13	V+	BATT–
14	open	BATT–
15	REF	BATT–
16	BATT–	BATT–

Table 3. Maximum charge time.

Programming the maximum charge time for fast-charge controllers (Maxim New Releases Data Book, 1994, p. 4-56).

Timeout (min)	A-to-d t_A sampling (seconds)	Slope charge limit	PGM3 pin	PGM2 pin
22	21s	Disabled	V+	open
22	21s	Enabled	V+	REF
33	21s	Disabled	V+	V+
33	21s	Enabled	V+	BATT–
45	42s	Disabled	open	open
45	42s	Enabled	open	REF
66	42s	Disabled	open	V+
66	42s	Enabled	open	BATT–
90	84s	Disabled	REF	open
90	84s	Enabled	REF	REF
132	84s	Disabled	REF	V+
132	84s	Enabled	REF	BATT–
180	168s	Disabled	BATT–	open
180	168s	Enabled	BATT–	REF
264	168s	Disabled	BATT–	V+
264	168s	Enabled	BATT–	BATT–

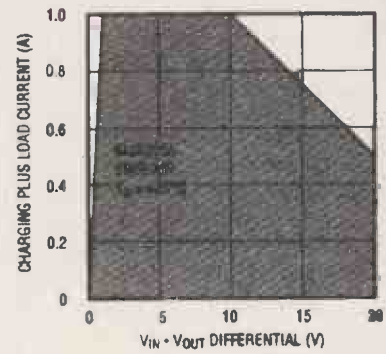

Fig. 2. Operating area of MAX713/MJD2955 circuit (Maxim Battery Management Circuit Collection, 1994, p. 2).

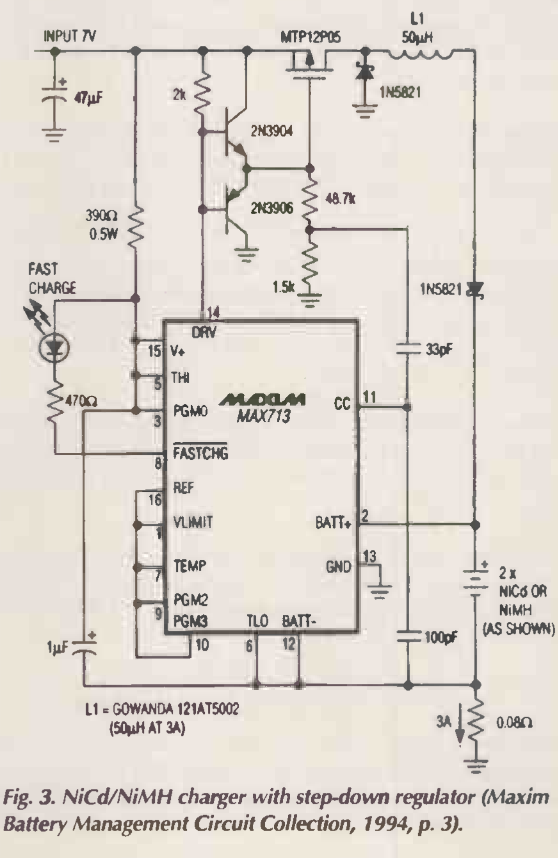

Fig. 3. NiCd/NiMH charger with step-down regulator (Maxim Battery Management Circuit Collection, 1994, p. 3).

internally generated 250mV threshold. The difference is amplified by a gain of eight, and the resultant error signal appears at the current-sense amplifier output on the CC pin.

A second high-gain stage between CC and DRV compares the error signal to the *MAX713* +2V reference, switching the *MTP12P05* p-channel fet on or off to regulate battery current.

The circuit operates in switch-mode rather than in the linear mode because of hysteresis introduced by the feedback divider and 33pF capacitor connected to CC. The capacitor injects charge into the CC node each time the p-channel fet turns on or off. This raises the error signal slightly above or below the +2V reference, and overdrives the second gain stage to ensure a fast-switching drive signal to the fet.

Current available for charging is 3A. This is determined by the value of R_{SENSE} connected at the BATT– pin (0.25/3A=0.08Ω).

Lower currents allow smaller external components. For example, for a 1A charger, R_{SENSE}=0.25/1A=0.25Ω. A 1A Schottky such as the *1N5818*s can be substituted for the *1N5821*s, and a Sumida *CD75470* surface-mount inductor can be substituted for the Gowanda part. The Sumida inductor has a value of 47μH and is capable of carrying 1A,

Also, higher input voltage can be accommodated by adding a level-shifter between DRV and the fet driver transistors (*2N3904*/*2N3906*) and changing the 390Ω shunt resistor value.

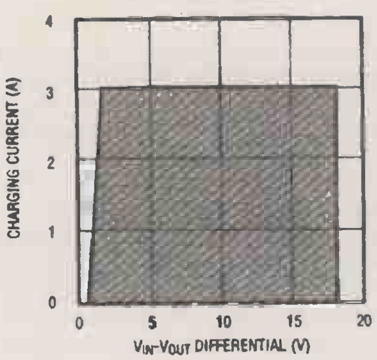

Fig. 4. Operating area of MAX713/step-down circuit (Maxim Battery Management Circuit Collection, 1994, p. 3).

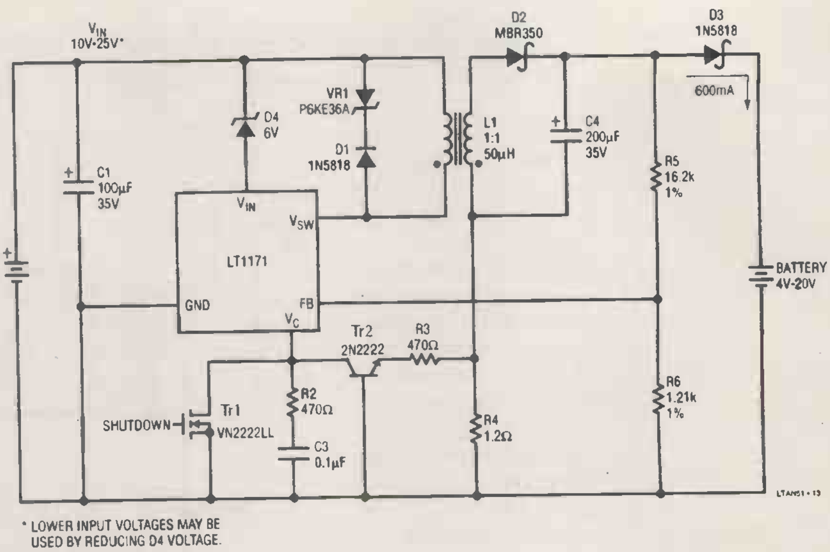

Fig. 5. Constant-current battery charger (Linear Technology, Linear Applications Handbook, 1993, p. AN51-11).

Constant-current battery charger

A Linear Technology *LT1171* can be connected for fly-back operation to provide a constant-current battery charger, Fig. 5. Note that this circuit can be used for either NiCd or NiMH technologies. It does not detect when full battery charge is reached. Nor does the circuit indicate a full charge. However, it does have an important advantage – battery voltage can be higher or lower than the input voltage. This is because of the fly-back configuration.

For example, a 16V battery stack may be charged from a 12V automobile battery. Charge current is sensed by R_4 and set at about 600mA. Resistors R_5 and R_6 limit the peak output voltage when no battery is connected.

Diode D_3 prevents the battery from discharging through the divider network when the charger is off. Transistor Tr_1 provides for electronic shutdown of the charger (if needed).

Dual-rate battery charger

The *1171* can also be connected to provide a dual rate battery charger, Fig. 6. Again, the circuit can be used for either NiCd or NiMH cells, but is it does not detect when full battery charge is reached. Also, the input voltage must be higher than

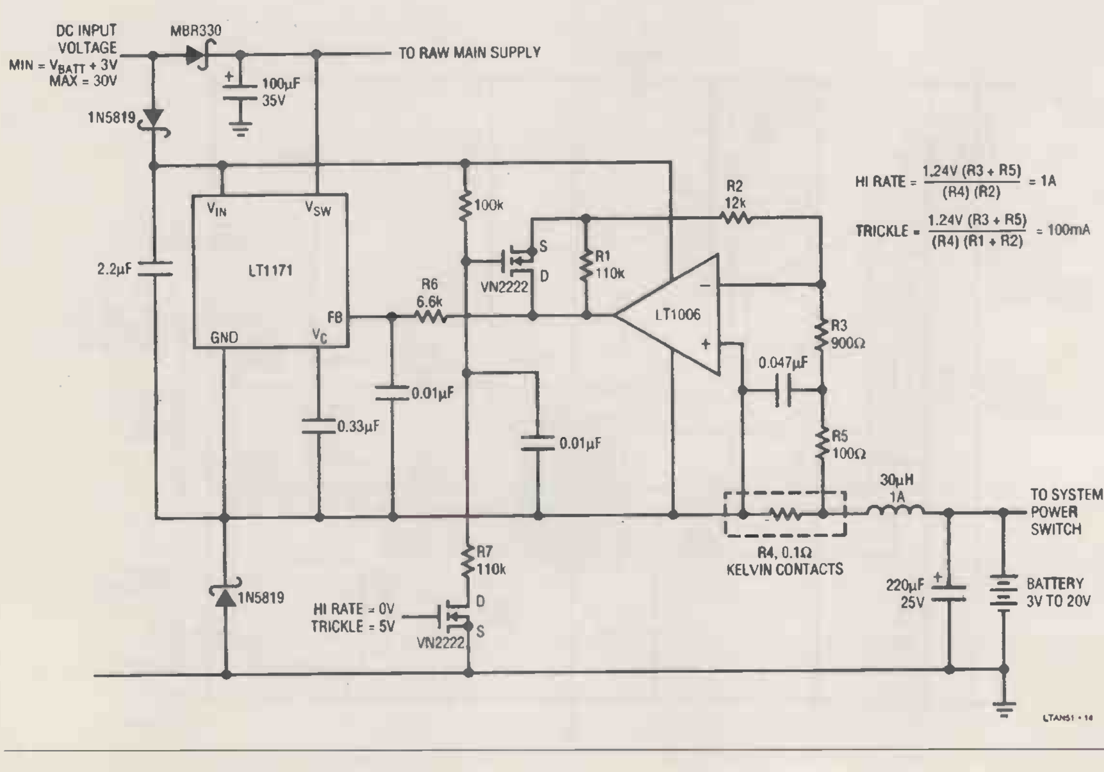

Fig. 6. Dual-rate battery charger (Linear Technology, Linear Applications Handbook, 1993, p. AN51-12).

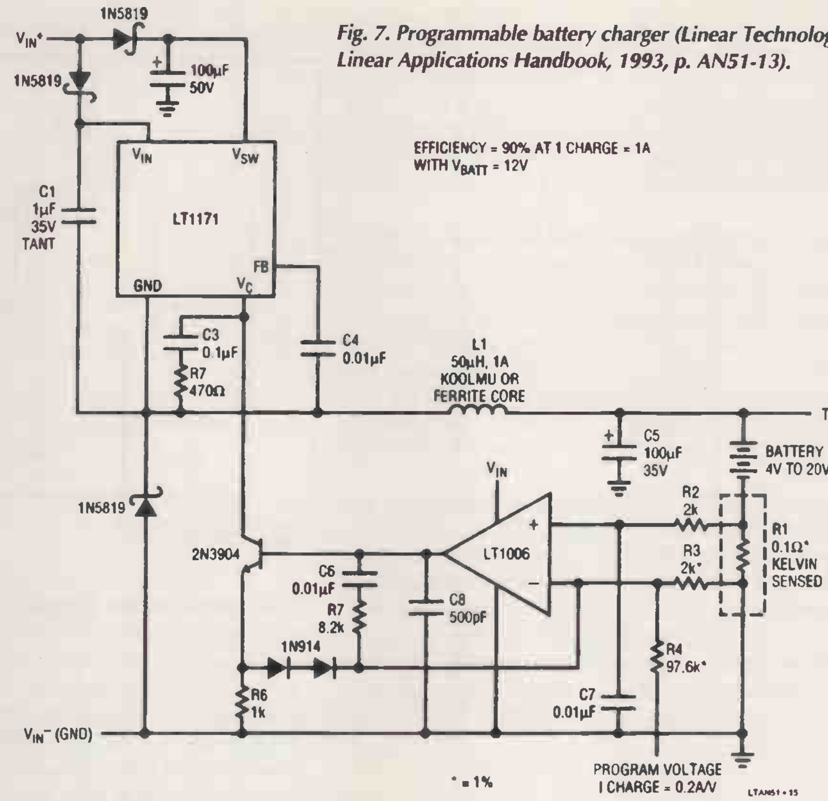

Fig. 7. Programmable battery charger (Linear Technology, Linear Applications Handbook, 1993, p. AN51-13).

the battery voltage for charging to occur. The primary advantage of this charger is efficiency – at around 90% when charging at maximum output current. Because of this efficiency, no heat sinks are needed on either the *LT1171* or the diodes.

A logic signal causes toggling between a high-charge rate, up to 2A, or a trickle rate. An *LT1006* amplifier senses the current in the battery and drives the feedback pin of the *LT1171*. The entire control circuit is boot-strapped to the *1171* and floats at the switching frequency. This means that stray capacitances must be minimised in component layout.

A transistor sets the gain on the *LT1006* by shorting or opening resistor R_1. For the values shown, this changes the charge rate between 100mA and 1A.

Programmable battery charger

The *LT1171* can be connected to provide a programmable charger for use with either NiCd or NiMH batteries, **Fig. 7**. This circuit does not detect when full battery charge is reached, and the input voltage must be higher than the battery voltage.

But the charging current is directly proportional to the program voltage, which can be controlled digitally via d-to-a converters if desired. A small sense resistor between the bottom side of the battery and its ground senses battery charging current. This is compared with the program voltage. From this comparison, a feedback signal is developed to drive the *LT1171* V_C pin, thus controlling the charge current. Typical efficiency during high charge is 90%, thus eliminating the need for heat sinks in most applications.

Four-cell regulator/charger for NiCd cells

It is possible to connect the *LTC1155* dual power-mosfet as a four cell charger/regulator, **Fig. 8**. The *1155* has the ability to deliver 12V of gate drive to two n-channel power mosfets when powered from a 5V supply with no external components. This ability, coupled with micropower current demands, makes the *LTC1155* well suited for high-side

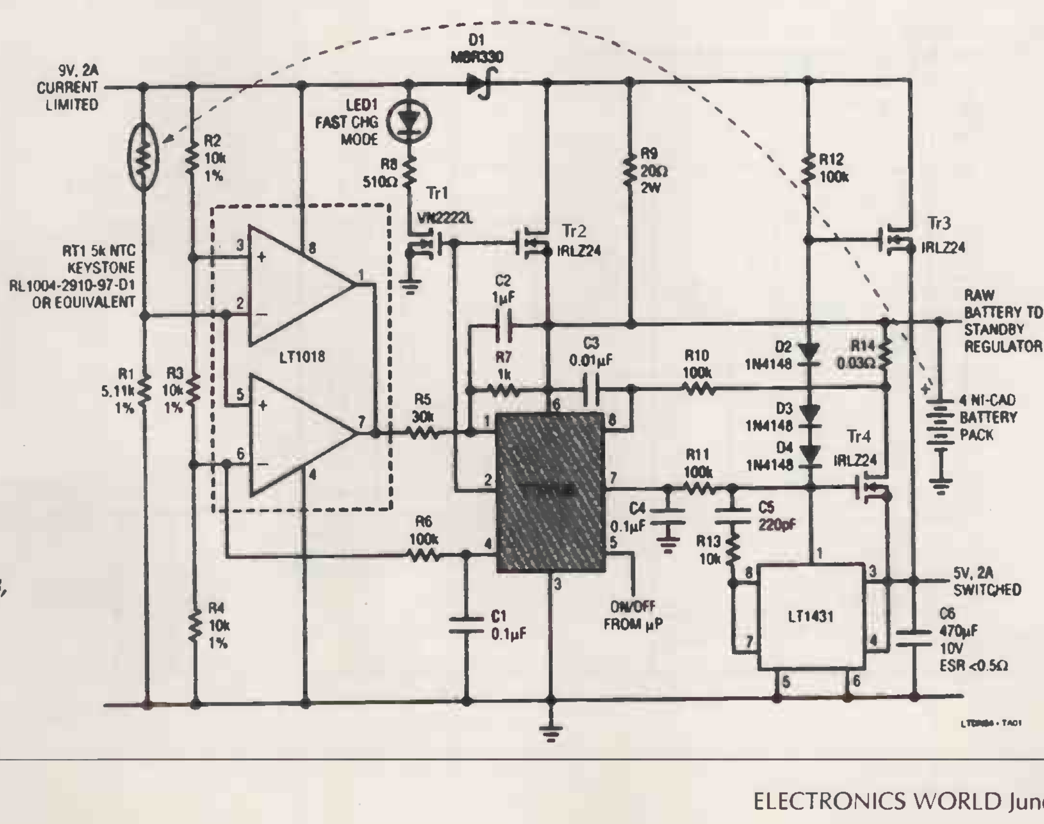

Fig. 8. Four-cell NiCd regulator/charger (Linear Technology, Linear Applications Handbook, 1993, p. DN51-1).

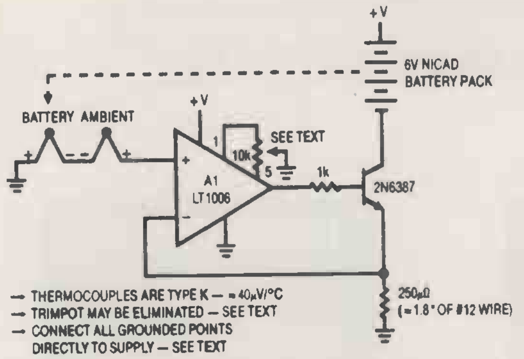

Fig. 9. Thermally-controlled NiCd charger (Linear Technology, Linear Applications Handbook, 1990, p. AN51-11).

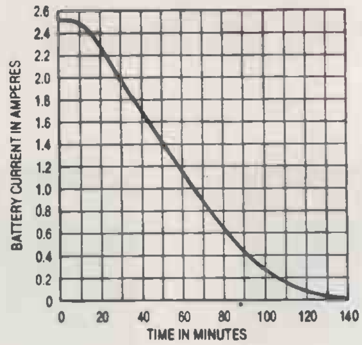

Fig. 10. Charge characteristics for NiCd charger (Linear Technology, Linear Applications Handbook, 1990, p. AN37-2).

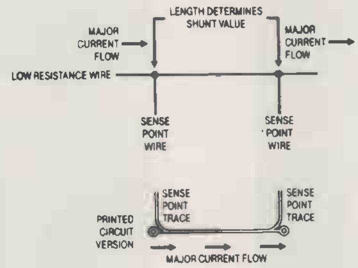

Fig. 11. Low resistance shunts for Kelvin sensing (Linear Technology, Linear Applications Handbook, 1990, p. AN37-4).

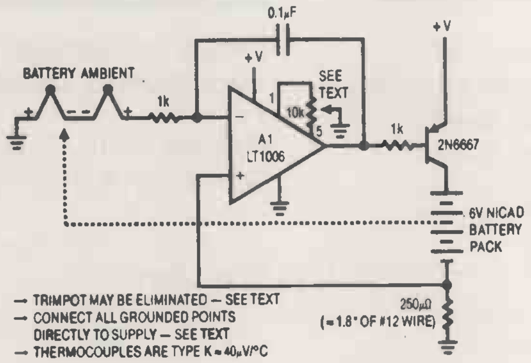

Fig. 12. NiCd charger for grounded batteries (Linear Technology, Linear Applications Handbook, 1990, p. AN37-2).

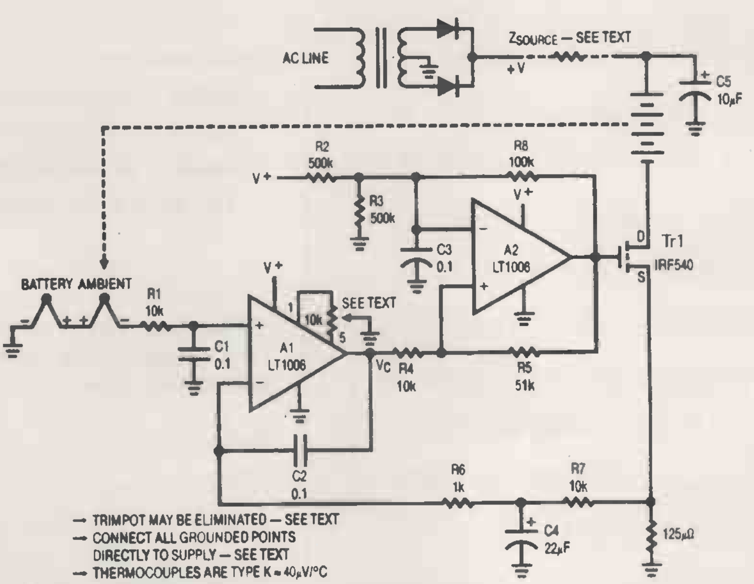

Fig. 13. Switch-mode thermal NiCd charger (Linear Technology, Linear Applications Handbook, 1990s, p. AN37-3).

switching applications. These generally require more expensive p-channel mosfets.

The circuit is well suited for a notebook-computer power-supply system powered by a four-cell nickel-cadmium battery pack. Such a charger consumes very little board space when the *LTC1155* and three power mosfets are housed in SO packages. But Tr_3 and Tr_4 must be provided with proper heat sinks.

One-half of the *LTC1155* is controls the battery-pack charging. The 9V, 2A current-limited wall unit is switched directly into the battery pack through an extremely low-resistance mosfet switch, Tr_2. Gate-drive output pin 2 from the *1155* generates about 13V of drive to fully switch both Tr_1 and Tr_2. Voltage drop across Tr_2 is about 170mV at 2A, so it can be surface mounted to save board space.

Inexpensive thermistor RT_1 measures the battery temperature and latches the *LTC1155* off when the temperature rises to 40°C. This is done through operation of the *LT1018* window comparator.

Input to the *LT1018* is determined by the RT_1 resistance, which, in turn, is controlled by battery temperature. When the temperature rises to 40°C, drain-sense input of the *1155*, pin 1, goes low. Use of a window comparator between the RT_1 thermistor and the *1155* also ensures that very cold battery packs below 10°C are not quick-charged.

Transistor Tr_1 drives an indicator lamp during quick-charge to let the computer user know that the battery pack is being charged. When the battery temperature rises to 40°C, the *1155* latches off, and the battery-charge current flowing through R_9 drops to 150mA.

A four-cell NiCd battery pack produces about 6V when fully charged, dropping to about 4.5V when the batteries are nearly discharged.

The second half of the *1155* provides gate-voltage drive, pin 7, for a low-voltage drop mosfet regulator. The *LT1431* controls the gate of Tr_4 and provides a regulated 5V output when the battery is above 5V. When battery voltage drops below 5V, Tr_4 acts as a low-resistance switch between the battery and the regulator output.

A second power mosfet, Tr_3, connected between the 9V supply and the regulator output, by-passes the main regulator when the 9V supply is connected. This means that the computer power is taken directly from the ac line while the charger wall unit is connected.

Regulation for both Tr_3 and Tr_4 is provided by *LT1431* which also maintains a constant 5V at the regulator output. Diode string $D_{2\text{-}4}$ ensures that Tr_3 conducts all of the regulator current when the wall unit is plugged in by separating the two gate voltages by about 2V.

Resistor R_{14} acts as current sensor for the regulator. When voltage drop between the second drain-sense input, pin 8, and the supply, pin 6, rises above 100mV, the regulator latches off at 3A. Resistor R_{10} with C_3 provides a short delay, and the microprocessor can restart the regulator by turning the second input, pin 5, off and then back on.

When the battery voltage drops below 4.6V, the regulator is switched off by the microprocessor. Stand-by current for the 5V 2A regulator is less than 10μA, and the regulator is switched on again when the battery voltage rises during charging.

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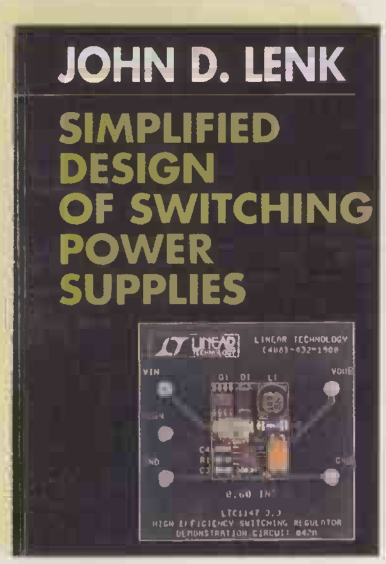

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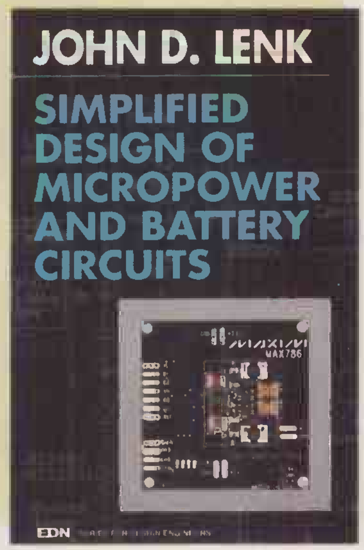

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Power dissipation within the notebook computer is generally quite low. As a result of fast-charging the battery pack, the current-limited wall unit dissipates most of the power. Transistor Tr_2 dissipates less than 500mW, while resistor R_9 dissipates about 700mW.

Transistor Tr_4 dissipates about 2W for a very short period when the batteries are fully charged but dissipates less than 500mW as soon as the battery voltage drops to 5V. The three ICs dissipate little power, though Tr_3 can dissipate as much as 7W if the full 2A output current is required and the unit is powered from the wall unit.

Thermally-based NiCd-cell charger

Thermocouples can be used to sense cell and ambient temperatures simultaneously. **Figure 9**, shows such an arrangement and **Fig. 10** its charge characteristics. The *LT1006* amplifier, A_1, furnishes the amplification necessary for microvolt-level thermocouple signals.

To understand operation of the circuit, assume that the battery pack is discharged. The battery thermocouple is directly mounted on one of the cells in the pack, while the ambient thermocouple is thermally insulated and mounted on a mass. This mass may be a frame or other part of the equipment. Both thermocouples are at the same temperature, and both produce the same voltage.

Under these conditions, the thermocouples are phase-matched, negative to negative, as shown. Their outputs cancel, and A_1 sees an input of 0V.

The 10kΩ offset-adjustment trimmer is set to introduce enough input-offset so that the A_1 output swings positive, turning on the transistor. Current flows from the supply, through the battery pack, and to ground via the 250μΩ shunt. The low-impedance shunt minimises losses, cost, and complexity.

Voltage across the shunt rises to about 625μV, which is the amount of off-set set by the potentiometer. This voltage is fed back to inverting input minus of A_1 and forms a basic amplifier-servo loop. The loop controls about 2.5A through the battery pack.

Low-resistance shunts can be constructed in a simple, inexpensive way using a small length of wire or a circuit-board trace, **Fig. 11**. The type and length of wire determines the shunt resistance, which can be altered to produce the desired charging characteristics. Figure 11 also shows the details for wire and circuit-board shunts. In both wire and pcb-track cases, the shunt should have separate Kelvin style connections for sensing so that the high current does not affect the readings.

The battery heats as it charges and this heat is picked up by the battery-mounted thermocouple. Temperature difference between the two thermocouples determines the voltage, appearing at the A_1 non-inverting input. As battery temperature rises, this small negative voltage becomes larger. Note that a 1°C difference between the thermocouples equals 40μV. Amplifier A_1 gradually reduces the current through the battery pack to maintain a balance between the inverting and non-inverting inputs.

The effect of this action over time, Fig. 10, is that the battery charges at a high rate until heating occurs, and then the circuit tapers or slopes the charge.

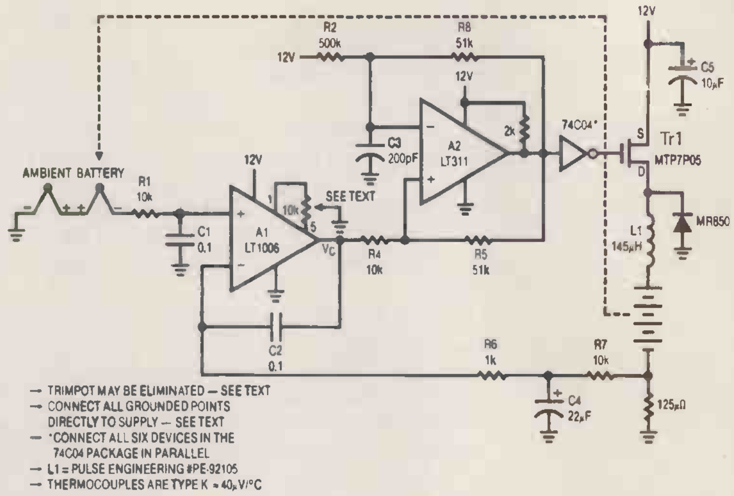

Fig. 14. Switch-mode thermal NiCd charger, low-impedance source (Linear Technology, Linear Applications Handbook, 1990, p. AN37-4).

Circuit values given in Fig. 9 limit the battery surface-temperature rise over ambient to about 15°C.

In a thermally based NiCd charger for use with batteries committed to ground, **Fig. 12**, the transistor is connected as a common emitter, so the inputs to amplifier A_1 are reversed. However, operation is the same as for the thermally controlled NiCd charger circuit.

Note that in Figs 9 and 12, the trimmer may be eliminated by specifying an *LT1006* set at manufacture to the desired offset value. The small shunt-sense voltage, of a few hundred microvolts at most, requires a high-quality ground for accurate results. This ensures that the large current flow through the transistor does not combine with ground-return impedances to create errors. The servo cannot tell the difference between voltages developed across a poor ground and those produced by the shunt.

In practice, all returns should be brought directly back to the supply common terminal.

Figures 9 and 12 both force the transistor to dissipate some power, particularly in the middle of the charge curve, and

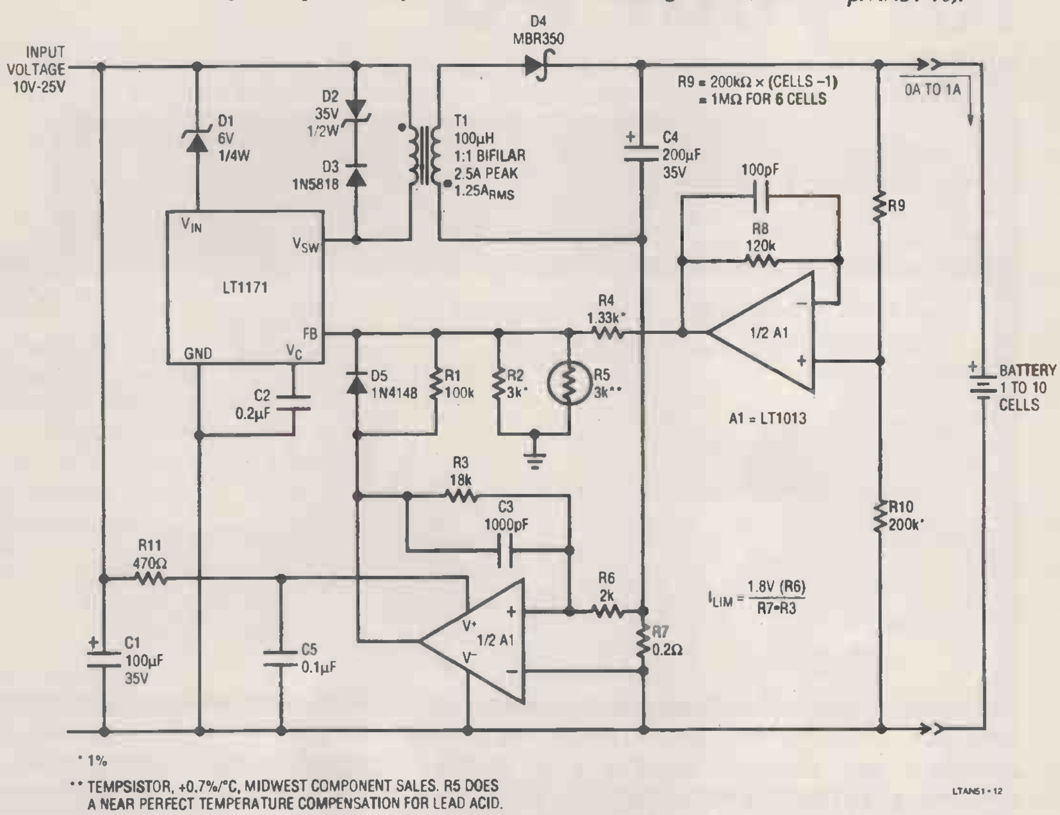

Fig. 15. Lead-acid battery charger (Linear Technology, Linear Applications Handbook, 1993, p. AN51-10).

heat may be a problem in very small enclosures. This is typical of many micropower circuits.

A circuit can be designed to eliminate this problem – though requiring a much more elaborate configuration, **Fig. 13**. This circuit is similar than the other circuits, except that an additional IC, A_2, is placed between A_1 and the output transistor Tr_1.

Op-amp A_2 functions as a duty-cycle modulator. Transistor Tr_1 – a power fet in this case – operates in the switched mode, delivering duty-cycle modulated-current pulses to the battery pack.

The *RC* network of R_7/C_4 filters the switching waveform to dc. Resistors R_6 and R_7 present a balanced source impedance to A_1, and capacitor C_2 sets gain roll-off.

The circuit relies on the source impedance of the wall transformer to limit current through Tr_1 and the battery pack. This parameter may be set when specifying the transformer.

If the charging source has low impedance, a circuit can be used where the output is essentially a step-down switching regulator, **Fig. 14**. The *74C04*s provide phase inversion, and drive, for Tr_1, which is a p-channel mosfet.

Lead-acid battery charging

Lead-acid rechargeable gel cells are attractive because of their high energy-density-per-unit volume. They have a long life expectancy when treated properly, but often suffer premature failure because of improper charging.

A charging circuit, **Fig. 15**, needs precise non-linear temperature compensation, constant-voltage charging with constant-current over-ride, and high efficiency over a wide range of input and battery voltage.

The basic charger is a fly-back design to allow operation with input voltages above or below battery voltage. Switching IC *LT1171* operates at 100kHz and can deliver up to 15W into the battery. A dual op-amp is used to control constant voltage and constant current modes.

Acting as a current limiter, A_1 turns on when charging-current through R_7 exceeds a present limit determined by R_3, R_6, and R_7. This current limit is included to prevent excess charge current for heavily discharged batteries. Losses in R_7 are kept low because the voltage drop across R_7 is kept to several hundred millivolts.

Lead-acid batteries have a non-linear negative temperature coefficient, which must be accurately compensated to ensure long battery life and full charge capacity. Resistor R_5 is a linear positive-temperature-coefficient thermistor. This characteristic is converted to the required non-linear characteristic by parallel connection with R_2. Combination R_2, R_3, and R_4 multiplies the 1.244V feedback level of the *LT1171* to the proper 2.35V level required by one cell at 25°C.

One-half of A_1 is used as a buffer to drive the resistor network. This allows large resistors, R_9 and R_{10}, to be used for the cell-multiplier string. Resistor R_9 is set at 200kΩ for each series cell over one. Current through R_9 is only 12μA, so R_9 can be left permanently connected to the battery. Resistor R_{10} is added to give the charger a finite output resistance of about 25mΩ per cell in a constant-voltage mode to prevent low-frequency hunting. ■

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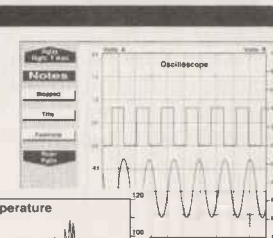

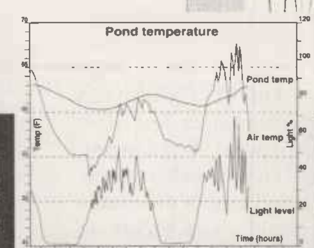

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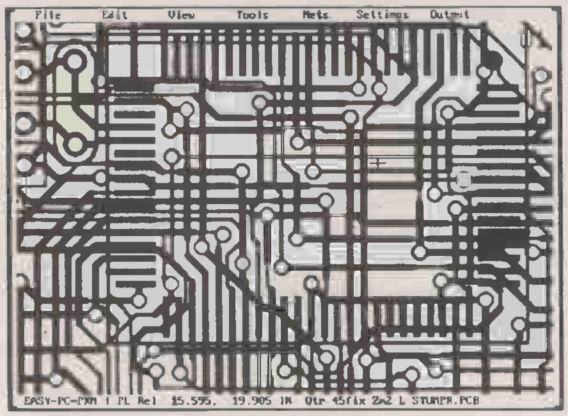

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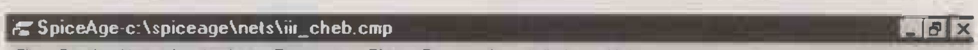

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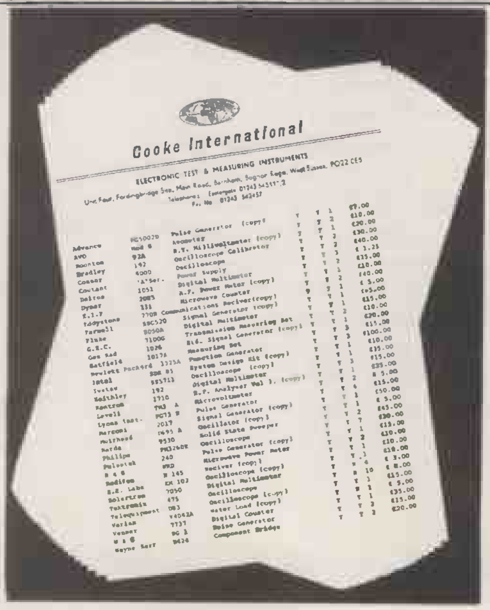

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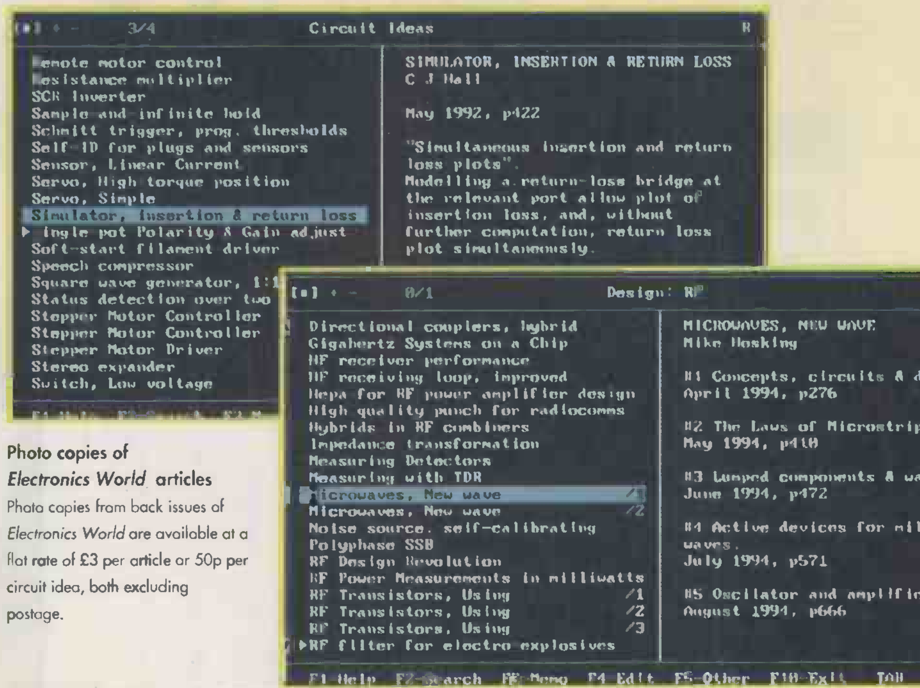

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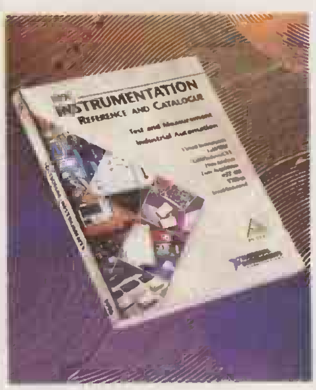

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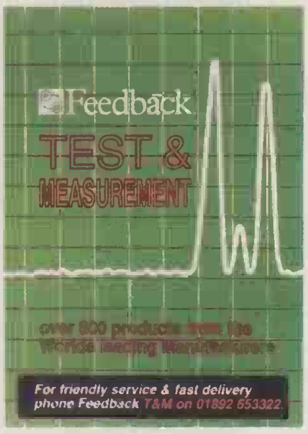

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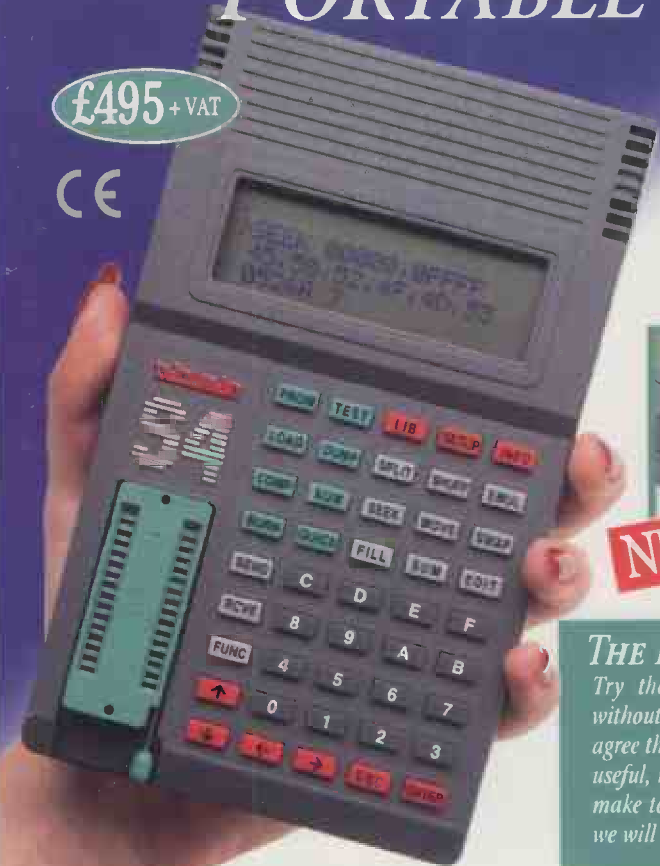

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