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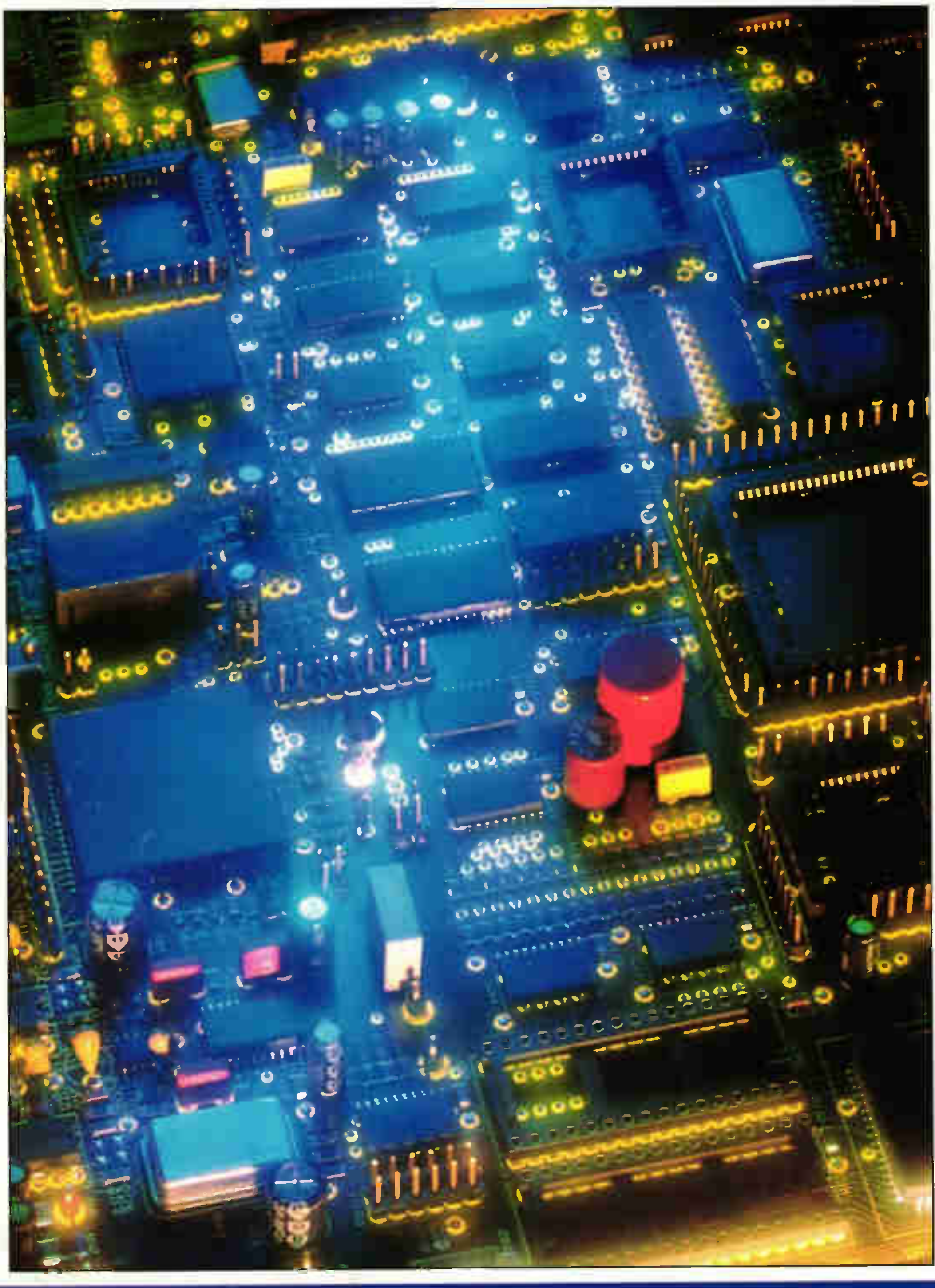

Designing with saturation

Exclusive: earliest tv recordings

Improving the stereo image

Linearising techniques

Telemetry via mobile phone

Simple 50-950MHz synthesiser

Patenting demystified

Fourteen Circuit Ideas – page 870

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Power distribution system combines aesthetics and versatility

The DB2000 modular power distribution system offers a stylish and flexible mains-power solution for office-based applications such as computer workstations, dealing desks, high-technology office furniture and LAN racking.

Modules are available with up to 15 standard BS1363 sockets and can be specified in horizontal or vertical configurations, with a single switch and/or fuse for each module or for each individual socket. In addition, there is a wide range of support modules to protect against earth leakage, overcurrents and mains transients.

Power may be fed from other modules or direct from the mains supply through re-wireable or pre-wired ST18 connectors.

Designed for safe and easy installation, the DB2000 modules incorporate a sliding shutter/locking mechanism which serves as a lock when the Wieland connector is inserted and as a safety shutter when the connector is removed.

The DB2000 system enables users to quickly configure a customised power distribution system, which can easily be altered at a later date to accommodate changing requirements.

CIRCLE NO. 101 ON REPLY CARD

200W switch-mode PSU for datacomms

Byfleet-based Safety Power Group has introduced a switch-mode power supply specifically designed for use in modular data-communications systems.

Known as the 48FS200-121, this high-reliability 200W PSU accepts input voltages in the range 42-72VDC and provides a single output of +5V at 40A. Its high MTBF figure of 100,000 hours is backed by a 2-year guarantee as standard.

Key features of the 48FS200-121 include convection cooling, reverse protection and undervoltage protection on the inputs, POWER OK and OUTPUT OK signals on the outputs, and a power-sharing facility that makes the PSU suitable for n+1 redundancy designs and 'hot' insertion/removal applications.

Mounted on a 4U x 9TE panel, the power supply carries a CE mark and complies with all relevant European standards for safety and EMC, including EN60950, EN55022, EN61000 and IEC801-5. In addition, it is designed to meet the BTNR 2511 in-rush specification.

Equipped with H15 DIN connectors as standard, the 48FS200-121 can also be fitted with additional accessories such as handles, mains switches, LEDs and test points. Operating temperature range is specified as 0 to 70°C, derating by 2.5%/°C above 55°C.

CIRCLE NO. 102 ON REPLY CARD

New 250W power supply features compact design

The new FL250 switch-mode power supply, available exclusively from the Safety Power Group, uses double-sided plated-through-hole PCB technology to achieve a low profile of just 43mm, thereby providing equipment designers with a valuable space-saving opportunity.

Manufactured in the UK by Ferrus Power, the FL250 is CE marked and carries all the necessary international safety approvals, including EN60950 and UL1950, as well as meeting the requirements of the EN55022 Class B, FCC Class B and CISPR 22 Class B standards for electromagnetic interference.

This new 250W power supply is available with single outputs of 5V @ 50A, 12-15V @ 17A, 24-28V @ 9A or 48V @ 5.2A or a choice of four multiple-output configurations.

The single-output models feature remote-sense capability and power-fail signals, and all versions offer overcurrent protection and 24/48V DC input facilities.

The FL250 has a typical full-load efficiency of 75% at 240Vrms and its operating temperature range is specified as 0-50°C, derating by 2.5%/°C up to 70°C.

CIRCLE NO. 103 ON REPLY CARD

150W PSU features universal input

Available from the Safety Power Group is a versatile 150W switch-mode power supply that offers a universal input and a wide choice of single or multiple outputs, making it suitable for use in applications.

Manufactured in the UK by Ferrus Power the FW150 is designed to comply with the EN55022-B, EN61000-4 and IEC801-5 electromagnetic interference standards, as well as the EN60950, UL1950 and CSA22.2 No. 950 safety standards.

The power supply can be specified with single outputs of 5V @ 30A, 12-15V @ 13A, 24-28V @ 6.5A or 48V @ 3.2A, all of which feature remote-sense capability and power-fail signals. Alternatively, four multiple-output configurations are available.

All versions feature a 90-264V universal input, together with 24/48V DC input and overcurrent protection facilities.

The FW150 comes complete with a 2-year guarantee as standard.

CIRCLE NO. 104 ON REPLY CARD

750W SMPSU for telecoms applications

Now available exclusively from Safety Power Group is the FR750 switch-mode power supply - a 750W unit that offers a wide range of single or multiple outputs and an array of advanced features that make it ideal for use in telecommunications applications.

The FR750 can be specified with single outputs of 5V @ 120A, 12-15V @ 56A, 24-28V @ 28A or 48V @ 16A or any one of six multiple-output configurations. Multiple-output versions achieve an MTBF of 80,000 hours, and for single outputs this figure rises to 120,000 hours.

Providing facilities such as current sharing, remote sensing, adjustable 'Power OK' signals, programming outputs and 24/48V DC input capability, the new power supply can be tailored to meet the requirements of most telecommunications systems.

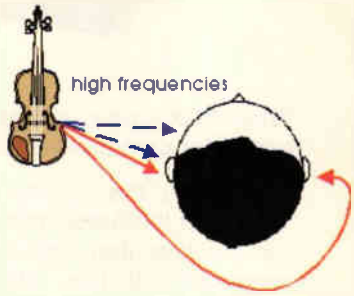
The FR750 carries a CE mark and complies with all relevant European standards for EMC and safety, including EN55022, EN61000, IEC801 and EN60950.

Housed in a chassis-mounting enclosure, the PSU is equipped with screw and stud terminals and is supplied with a 2-year guarantee.

CIRCLE NO. 105 ON REPLY CARD

Contents

Special offer voucher details – turn to page 820



Views on how to get the best stereo image are changing. See page 830.

What's is it? This – and well over forty other recently introduced items – are featured in New Products starting on page 879.

Using image-recovery techniques, Don McLean has revealed television pictures recorded on disc as early as the twenties, page 823.

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Borrow, learn then leave

It's much harder being a student today than it was twenty five years ago. Not that standards have changed significantly; the reason for this state of affairs is money.

Students in the seventies had none of the financial problems that confront students of today. The reduction of the maintenance grant to almost nothing and the introduction of an additional tuition free of £1000 a year causes even more grief and hardship. Yes, student loans are available, and it's easy to accumulate a debt of several thousand pounds on graduation – to be paid back once the graduate goes into employment.

But starting a working life with a debt as large as this is a daunting prospect. What happens if the graduate should choose to get married to another graduate – which is more often the case than not? The combined debt could easily exceed £12000. And the couple will probably want to buy a house, which means securing a £50000 mortgage. Rather them than me.

Furthermore, what if an electronics graduate wants to do postgraduate study? Fortunately, studentships for Master's degree are not means tested – but they only last a year. Then of course, some will want to a Ph.D. This means another two or three years – or even more. By this time newly qualified electronics engineers with their B.Eng., M.Sc. and Ph.D. will have accumulated a very disturbing debt before they even find a job.

What is the starting salary in Britain for an electronics engineer with a Ph.D? £18000 to £20000 tops. Doesn't sound too bad except for the fact the student may have accumulated a sizeable debt before work begins. Then they look at jobs in the USA. The starting salary for a design engineer in Silicon Valley is around $60,000 – which is much more attractive.

But what about the debt that the newly qualified engineer amassed as a student? Simple, once you're in the States and you have no intention of returning to the UK to live, you forget it. Start with a clean slate and a salary of $60000 – almost twice the amount that could be earned in the UK

Sadly though, the country that paid for the engineer's education is left with the debt and gains nothing from the engineer's future contributions as a designer.

Will we see a new brain drain of British engineering talent to the USA? Is it happening now? Will it happen in the future? Can you blame the students? And what measures should be taken to prevent the USA siphoning off our most able designers?

In the sixties and seventies, every student had a means-tested grant to live on, which covered accommodation, books and living expenses. Although not excessive, it was certainly adequate and there was no need for any student to accumulate a large overdraft.

One solution is to have Undergraduate Engineering Studentships, or UESs, which does the same as the previous grant system by covering the living costs and fees for students on electronics degree courses. On graduation, students would not have a debt hanging around their necks and would probably be less inclined to emigrate to the USA.

But even this scheme will have difficulties; which degree courses should have UESs attached to them? If only some universities get UESs, what happens to the others? Will it mean mass unemployment for electronics lecturers? Very few students would choose an electronics degree course without a UES. And who should decide which universities get UESs?

Should the IEE decide by accrediting degree programmes? I think not. Since the IEE's goal posts for membership shift periodically, this institute is not in the best position to judge.

Don't forget that engineering degrees are considerably more difficult and intellectually demanding than softer options. We need to encourage our young people to take up electronics in preference to fluffy subjects.

Every British born student who is accepted onto a Single Honours degree – B.Sc. or B.Eng. – in electronics or electronics engineering in a British university should be funded for the full duration of the programme. Unless this happens, the shortage of electronics design engineers will be even more acute in the future than it is at present. ■

Dr Allen Brown

● Nick Prentice, on finishing his education, set up his own business. Doing well, and keen to put his venture on a firmer footing, he went to the TSB to open a business account. Nick says he was refused such an account on the grounds that he has not finished paying off his student loan. Does anyone have any similar stories? Ed.

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UP DATE

Companies say "no thanks" to SLIM EMC rules

A UK trade association is lobbying the European Commission (EC)against changing the EMC directive, a move that would herald more expense for hard pressed electronics firms.

Gambica, representing the instrumentation, control and automation industry, argues that changes should not be made to the regulations just for the sake of it.

Proposed changes are part of the EC's SLIM initiative. SLIM aims to simplify product legislation and give all directives a common format.

"SLIM aims to simplify regulations so they're not oppressive and detrimental to companies' effectiveness," said Ian Clasper, senior executive at Gambica.

However, in the EMC directive's case, changes so soon after introduction would mean even more expense for UK companies.

"We like SLIM and the idea of reducing the regulations, but in terms of the EMC directive we don't want it changed at this time," Clasper said.

John Whaley, general manager of test house SGS, agrees: "The EMC directive is complicated, but the reality is that everyone has come to terms with that complication, and it should not be radically changed."

Clasper maintains that the EMC directive has already been costly for European companies. "Why change it without justification?" he asks.

Clasper believes the only justification for SLIM, and a far better use of its time, is harmonising standards across the world.

"The EC should not change the EMC directive. It should take account of international trade and try to harmonise the standards worldwide," he said.

Richard Ball, *Electronics Weekly*

Mobile phone may soon answer back

Speech recognition and text-to-speech technologies will be added to mobile phones from Ericsson next year.

The Swedish telecoms giant has licensed the technology from Belgian speech company Lernout & Hauspie.

"There will be a couple of products coming out with speech recognition next year," said Jan Ahrenbring, v-p of marketing and communication at Ericsson Mobile Communications.

Initially only on high-end mobile phones, the features will include voice recognition instead of push button dialling and the ability for the phone to turn E-mails and messages into speech.

Hands-free operation is a desirable option, especially when the mobile is used in cars.

For the mobile to synthesise a voice to read back E-mails and messages is easier than reading the text of a long message from a mobile phone's small display.

"A speech user interface is ideal to address these challenges," said Jerry Calabrese, president of L&H's core technology division.

To keep down the amount of processing power and memory for these features, Ericsson has also licensed L&H's speech compression technology.

"This is because all speech recognition technology takes a lot of space," said Ahrenbring.

The three technologies - speech recognition, text to speech and compression - were also licensed by Motorola earlier this year.

The company could use the systems in mobile phones and other products such as handheld computers.

Richard Ball

Only 1 in 4 companies mention 2000 Bug

Three quarters of companies make no mention of tackling the Millennium date problem in their annual reports, according to a survey of 400 companies. The survey, by analysts Company Reporting, found that those who do flag it up seem over-optimistic about the results of their efforts.

Engineers' pay deals are still falling

Pay settlements in the engineering sector have fallen for the third consecutive month. According to the latest figures from the Engineering Employers' Federation, the average settlement level to the end of June fell to 3.5 per cent, down from 3.6 per cent for the previous three months.

Phone health case goes before the judge

A court action intent on forcing mobile phones to carry health warning labels has been adjourned until September.

The private action by Roger Coghill of Coghill Research Labs, a bio-electromagnetics laboratory, is against a local mobile phone distributor for allegedly contravening the 1987 Consumer Protection Act. Coghill started the action after Trading Standards declined to pursue it. "Someone, somewhere has to do something," said Coghill.

He wants labels fitted which warn that prolonged continuous use of a mobile phone, in excess of 20 minutes, may endanger health. "What I'm trying to say is there is serious scientific concern that there's a problem with mobile phones," said Coghill. "What is coming out is the possibility that they're not safe if used for a long time."

There have been several recent mobile phone health scares including reports of short term memory loss and damage to unborn babies .

Electronics sector is still buoyant

The electronics sector is avoiding the recession currently affecting UK manufacturing, according to a report from Oxford Economic Forecasting.

It predicts the electronics sector will grow by 2.5 per cent in 1998 despite manufacturing firms having to contend with a 'seriously overvalued' exchange rate and the effects of the Asian crisis.

The report stresses that not all the manufacturers' woes are due to market forces. It criticises manufacturers' productivity performance over the last few years, describing it as appaling.

In particular it highlights the limited investment by UK firms - including electronics one – in new equipment over the last few years. "Although unit labour costs – a measure of productivity – fell in the electronics sector in 1997, it had two poor years in 95 and 96," said report author Alan Wilson.

The overall outlook for manufacturing is pretty gloomy, claims Wilson. "There are no signs of an upturn: all the indicators are pointing down."

The Confederation of British Industry (CBI) has also reported that export orders last month fell at the fastest rate for 12 years. "UK manufacturers are clearly running into considerable difficulties," said Andrew Buxton, chairman of the CBI's economic affairs committee.

An arresting development

A language translator from Belgian firm Lernout & Hauspie is being used in the fight against international organised crime.

Europe's new crime enforcement agency – Europol – is using the T1 translator to overcome the problems of multi-lingual communications.

Documents in any major European language are translated in seconds to another language.

The system is being trialled in Spain. Information on drug trafficking is translated into English and distributed to other drug enforcement officers around Europe.

"In the fight against drugs, speed is often key to a successful operation. We can now translate between English and Spanish and vice-versa in seconds. This is a considerable benefit," said Klaus Schimdt, Europol's project coordinator.

Is V-chip necessary?

An industry television group has questioned the need for the V-chip to control access to violent or sexually explicit TV programmes in the UK.

The group – made up of the BBC, the ITC and the Broadcasting Standards Commission - said that broadcasters should give clear guidance about TV violence instead of relying on electronic devices.

"The V-chip and other electronic gate-keeping devices offer only an inadequate quick fix solution to the problem of regulating violent content on television," reported the group. It also suggested that any use of electronic methods for regulating TV viewing should be carefully assessed following their introduction into the UK.

Reconditioned pcs going for a song

ICL is targeting small businesses and home users with pcs as cheap as £200. The pcs are part of a recycling scheme ICL is offering its large customers, in which unwanted desktop and notebook pcs are reconditioned and sold to the public through a chain of dealers. The pcs range from a sub 50MHz 486 for £199 to £348 for a Pentium clocked above 100MHz. For nearest dealer ring 01925 435431.

SVGA flat-panel chips

National Semiconductor announced what it claims is the industry's first SVGA/UXGA compliant chipset for next generation, high resolution flat panel monitors. The *DS90C387* and *DS90CF388* LDI chips are based on National's low voltage differential signaling technology.

Spot the difference... Signum Technologies of Cheltenham has developed a way of marking digital images to enable tampering to be detected. "The marks are undetectable to the eye,"said company technical director David Hilton. "This is different from digital fingerprinting which makes visible changes."

Called VeriData, the product authenticates an image by adjusting a quarter of the image's pixels by ±1bit. This not only allows alterations to be detected but adds a number to the image which can be used to identify where the image was authenticated. Digital fingerprinting, as provided by Signum and others, is a more robust process used for copyrighting. This uses bigger changes to add identification marks that can survive compression and photocopying. VeriData is aimed at digital images used in court, and is also applicable to digital sound recordings.

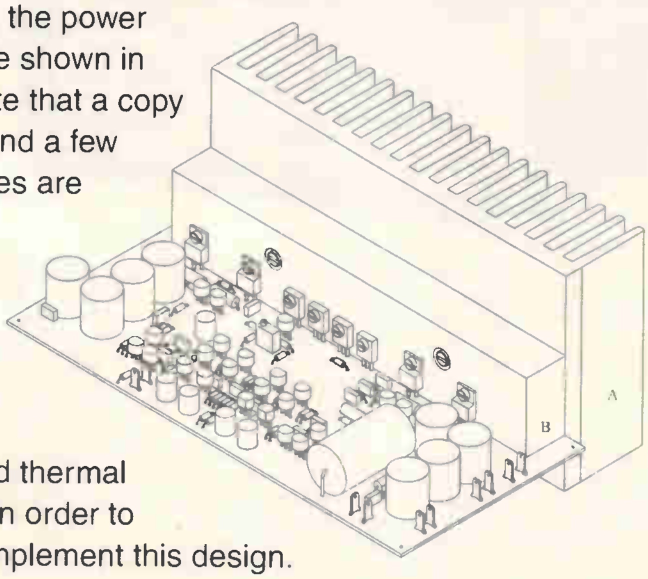
Power amplifier circuit boards

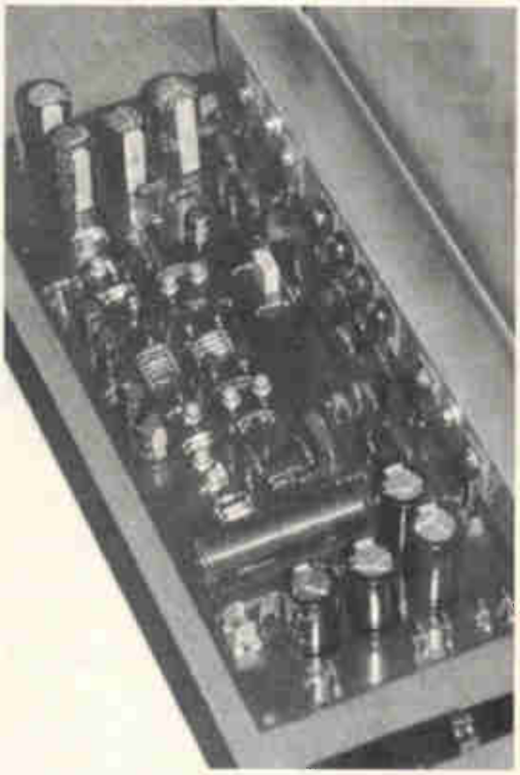
£42 per pair fully inclusive or £25 each

Professionally designed and manufactured printed circuit boards for Giovanni Stochino's no compromise 100W power amp are available to buy.

These high-quality fibre-glass reinforced circuit boards are designed for Giovanni Stochino's fast, low-distortion 100W power amplifier described in the August 1998 issue. Layout of the double-sided, silk screened and solder masked boards has been verified and approved by Giovanni.

This offer is for the pcbs only. The layout does not accommodate the power supply scheme shown in the article. Note that a copy of the article and a few designers' notes are included with each purchase, but you will need some knowledge of electronics and thermal management in order to successfully implement this design.





Giovanni's high-performance power amplifier mounted on its heat sink.

Please send me___ pcbs @ £25 each or £42 a pair.
I enclose my cheque for £ _____
Please debit my credit card for £____
Card type MasterCard/Visa.
Card number ________________ Expiry date ____/____
Signature ________________

Name________________
Address________________

________________ Tel________________
Cheques made payable to Reed Business Information.
Post to: PCB Offer, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS. Please alow 28 days for delivery.

Specifications

Power into 8Ω load	100W
Small-signal bandwidth before the output filter	20Hz (–0.1dB), 1.3MHz (–3dB)
Unity gain frequency before the output filter	22MHz
Output noise (BW=80kHz, input terminated with 50Ω	42μV rms
Measured output offset voltage	+32mV

Distortion performance

V_{out}, pk-pk	1kHz	20kHz
5	0.0030%	0.0043%
10	0.0028%	0.0047%
20	0.0023%	0.0061%
40	0.0028%	0.0110%
80	0.0026%	0.0170%

Slew rate

Positive slew-rate	+320V/μs
Negative slew-rate	–300V/μs

Disagreement looms over next digital TV standard

Set-top box manufacturer Pace Micro Technology is predicting the end for the European DAVIC cable modem standard, with a US-developed system taking a lead.

The UK's largest cable company, Cable & Wireless Communications has ordered 100000 set-top boxes which will use the multimedia cable network system (MCNS) rather than DAVIC, the European digital video broadcast (DVB) standard. Other European cable companies are following suit, said Pace.

"We would love to have backed a European standard, but we're a commercial company and we have to back a viable standard," said Andy Trott, director of engineering for networks at Pace.

Trefor Hooker, marketing manager of operating system supplier Microware, has the opposing view. "I would actually disagree. DVB has been going considerably longer than MCNS in the US," said Hooker.

"Lots of people are implementing the DVB specification worldwide. There are working solutions today," Hooker said. Microware supplies the OS for a DVB set-top box sold in Hong Kong.

Pace claims that silicon conforming to DAVIC is not yet in large scale production. Even when it is released, no one is sure whether the devices will actually work together.

"There isn't an interoperablity testing lab available," said Trott, whereas MCNS has had such a lab since September 1997.

"Manufacturers using DAVIC are relying on the silicon working first time," he said.

"It's very simple, and not many people like to hear it, but DAVIC is just not available," summed up Trott.

Richard Ball

Polymer batteries pass test phase

Lithium Technology of Pennsylvania has finished testing its lithium-ion polymer battery for portable computers.

"We have been developing this battery with a notebook computer maker,"said company president David Cade. "I can't say which one but it's in the top ten."

Lithium-ion polymer batteries are entirely solid state, having no liquid electrolyte inside. They can be made extremely thin – less than 0.5mm – and with a high energy density.

These attributes make them suitable for notebooks, laptops and mobile phones.

High internal resistance, leading to poor current delivery has been a characteristic of lithium polymer cells.

"We have no problems at all with this," said Cade. "We use carbon fibre webs in our batteries, which give us all kinds of advantages in structure, conductivity and pulse discharge rates."

Using these webs, said Cade, also simplified manufacturing.

"It allows us to use low cost coating techniques developed for the paper industry," he said.

Cade is cautious about predicting a date for commercial manufacture: "To be safe I would say we will go into production early next year."

Electronics driver info goes ahead

The government is to press ahead with electronic driver information and control networks as part of its drive to cut further road building. Transport minister John Reid announced a major cutback in the roads programme last week and an expansion of the use of automatic incident detection systems. He said more use is to be made of automatic traffic monitoring systems and computerised traffic models to provide information to improve traffic management. Such techniques have been effective in the Midlands and the government's White Paper, A New Deal for Trunk Roads in England, foresees a major expansion of such technology as a means of cutting congestion. ■

Voice analysis detects one too many

Doing the decent thing and nicking someone's car keys to stop them driving home drunk could become a thing of the past if Samsung gets its way.

It has applied for a patent covering an in-car anti-drink driving device which uses voice analysis.

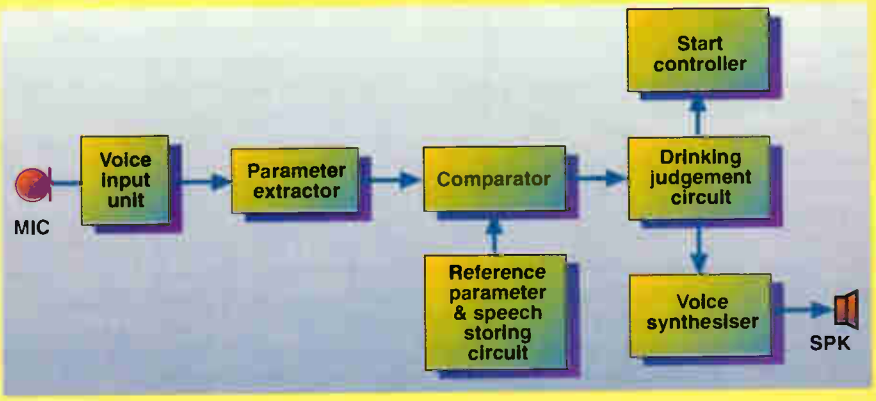
The potential driver speaks to the car's computer as they prepare to drive away.

A parameter extractor in the computer generates a "linear prediction coefficient-cepstrum coefficient after producing a linear prediction coefficient by taking an auto-correlation" – according to the patent – on the incoming voice signal.

It compares this coefficient with a parameter extracted when the driver was sober. If the coefficients match, the person can drive away, if not, they can't.

Presumably the concept could be extended as an anti-theft measure by preventing people with unfamiliar voices driving the car away.

Samsung does not say whether it has a working prototype.



The Chartered Institute of Patent Agents, a professional body similar to the IEE in electronic engineering, has put together a guide to answer some of the most frequently asked questions from budding inventors.

Stake a claim

"You can't patent an idea."
You can't patent abstract ideas, such as a mathematical formula, but a patent can give protection broad enough to cover the concept or principle behind a new technological effect or product.

"Patenting is expensive."
Worldwide protection may eventually cost a lot of money, but an initial British 'provisional' patent application is relatively inexpensive and creates an option for filing overseas for 12 months. It is important to bear in mind the costs spent in realising the invention, those necessary to develop it commercially and the likely returns when the product is marketed.

"It is better to rely on secrecy than to patent?"
For some inventions, such as complex recipes, it might be better to keep the details to yourself than to tell everyone about them in a patent. However, most inventions can't be kept secret. Before long someone will find out the details, the invention will no longer be new, and patent protection will not then be available.

"Inventions are protected automatically by copyright"
Copyright only protects 'works' which are artistic, literary, musical, etc. Most technical inventions can only be protected by patent, not copyright.

Mr inventor... Sir Clive Sinclair is an inventor's phenomenon. Since 1972 he has amazed and infuriated the British public and industry-watchers alike. From the first pocket calculator, via the first genuine home computer to the bizarre C5 electric bicycle.

"Protection is possible by posting details to yourself or your bank manager"
This is certainly useful to prove an invention has been made by a particular date, but it provides no protection at all. For this to be achieved a patent application must be filed and then the application must be granted.

"When you get a patent, you can't afford to enforce it"
A full scale court action can cost a fortune – for both sides. There are examples of private individuals suing large companies, in some cases with legal aid. In practice most companies don't waste time and money going to court and will often prefer to take a licence or reach some other agreement.

"Large manufacturers will steal your invention and ignore your patent"
If the invention is any good, the manufacturer will want to buy your patent, so that it can be used and competitors kept at bay. The invention might be stolen, but the patent could be enforced.

"You can't stop them taking your ideas in Taiwan"
As countries become more developed, it becomes more in their interest to respect patent rights. If protection is not obtained in countries such as Taiwan, others there can lawfully use the invention, but import into a country where you have a patent could be prevented.

"Can I do it myself?"
Of course you can – if you have the spare time to find out about all the procedures – and the British Patent Office is very helpful in explaining the various official requirements.

The Chartered Institute of Patent Agents
Tel: 0171 405 9450
Web page:
http://www.cipa.org.uk

Patents in a global framework

Patents are granted for new inventions and give their owners the right to stop anyone else from making or using that invention for a limited period.

British inventors have had the right to patent protection for their inventions since as far back as the 17th Century and earlier.

In the past, some countries, such as China – and even the Netherlands – tried doing without patents but soon found that this was not a good idea.

Now virtually every country in the world has a patent system; and the right to protection for inventions is enshrined in many important national and international laws and agreements such as the Declaration of Human Rights, the US Constitution and the World treaty on fair trade (GATT).

This is one area where international cooperation really works. Countries have been bringing their laws into line and agreeing treaties for a long time. One of the most important treaties on international patenting, which includes almost all countries, has been operating since the 19th Century. The European Patent Office opened for business in Munich in 1978, and at the same time the World Intellectual Property Office in Geneva started accepting International patent applications.

So, patents are important – for business, for the country, for the world.

Be realsitic...

"If you have a patent, you can stop everyone using your invention"
This may be difficult to realise in practice. A balance of licensing some and preventing others may produce a greater commercial return.

"Invent a better mousetrap and the world will beat a path to your door"
Manufacturers are undoubtedly cautious before incurring the often considerable expense required to develop and market a new product. Inventors have to become salesmen once their inventions are made!

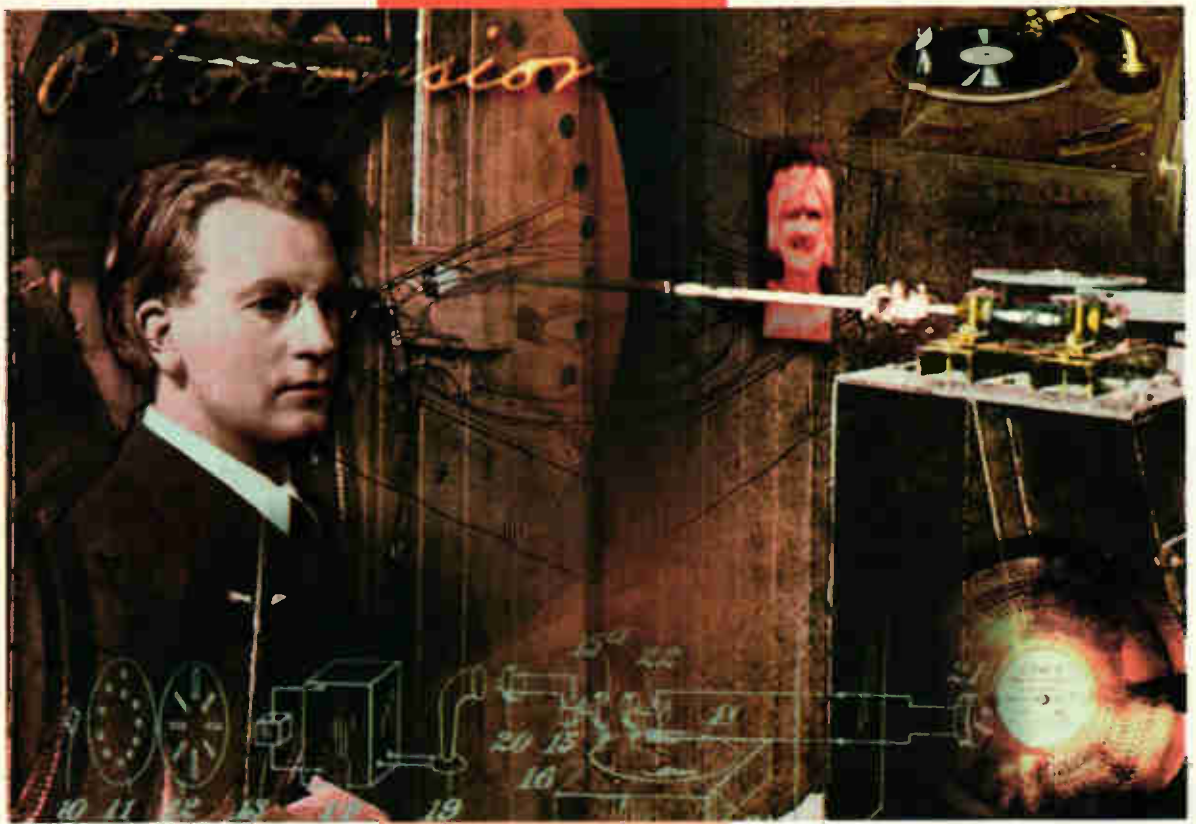
"Confidentiality may be better until you know whether it is worth patenting"
It is possible to approach manufacturers under a cloak of confidentiality to see if they are interested in the invention, this does not prevent you patenting later if they are interested, but it is difficult to prevent ideas leaking out. Also, some manufacturers refuse to consider ideas in confidence, because it puts them in an awkward position if they are already working secretly on the same idea. Manufacturers usually prefer to consider patent protection already applied for when dealing with inventors The conflicting aspects ore best discussed with your patent agent.

"If your invention is taken up, you will get a lot of money"
Hopefully this will be true, but there is never any guarantee that the product will sell well. Proper advice is needed as to the kind of deal to do with a manufacturer, and this also should be discussed with your patent agent.

"If your invention is really good, a manufacturer will buy it up to keep it secret"
Patent applications are published at an early stage, and then there is no possibility of secrecy any more. To keep it secret the manufacturer would have to buy your invention at a very early stage and then withdraw the application before publication. The manufacturer could then be stuck with an expensive lack of protection, if someone else came up with the same idea, or if the idea leaked out. In practice, there is no evidence of inventions being suppressed, and logically this is unlikely to be in any manufacturer's long term interests.

However, the value of a patent depends critically on the wording used, and professional assistance and expertise can make all the difference between a valuable patent and a worthless piece of paper.

"You can't trust patent agents"
Inventors are understandably – and indeed should be – wary of telling strangers about their ideas. Even so, patent agents are bound by professional regulations controlled by Royal Charter and have a total duty to respect confidentiality, their work is critically based on this. ■



Restoring Baird's image

For the first time, Don McLean reveals detailed new information from the world's earliest recordings of television.

John Logie Baird recorded television images in his laboratory in London soon after giving the world's first demonstration of television. This was well before television broadcasting began.[1]

Baird made the recordings with a view to developing a mass-market videodisc player. But he did not succeed, primarily due to distortion during recording.

Studying the signal and its faults yields the first detailed information on Baird's equipment and the problems that he encountered. Correcting the faults gives us the first television images from the dawn of television.

The first video disc

Baird's television 'standard' of the late twenties comprised only 30 lines per picture shown at 12.5 pictures per second. The bandwidth was narrow enough for the signal to be handled like audio.

Baird used this to attempt a means of capturing television images onto audio wax cylinders and discs, **Fig. 1**. He called this process 'Phonovision'.

His 1926 patent[2] described the basic idea of simultaneously recording vision and sound signals. In 1928, he filed for a patent[3] on the 'Phonovisor'. Had it been successful, the Phonovisor would have been the world's first consumer videodisc in a combined playback *and* display system. Its extreme simplicity of construction would also have made it low cost.

We know from the work described here that the duration of a disc with vision and sound could have been only a minute or so. This would have been sufficient for a music video similar – in marketing terms at least – to the *TelDec* system of the seventies and cd video singles of the eighties.

Baird's videodisc system never became a product[4] despite the experiments being heavily promoted. Bizarrely, Baird did demonstrate the *sound* of the vision signal. He declared[5] that he could recognise something about the subject from listening to the vision signal. Very likely, he only did this to suggest that he was making progress.

First sightings

In June 1928, Baird reported that he had managed to see a "crude smudgy" rendition on playback but that it was "more of a curiosity".[6] By 1931,

Donald F McLean
B.Sc(Hons) CEng FIEE

Fig. 1. The Phonovision discs all resemble 25cm (10in) diameter single-sided 78rev/min 'shellac' audio discs. A distinguishing feature is the radial structure caused by Baird's synchronous recording method.

Fig. 2. Most Phonovision discs have a dated 'Columbia Graphophone Company TEST RECORD' label. This one is from the earliest known recording of television, featuring a rather wooden performance by 'Stookie Bill'.

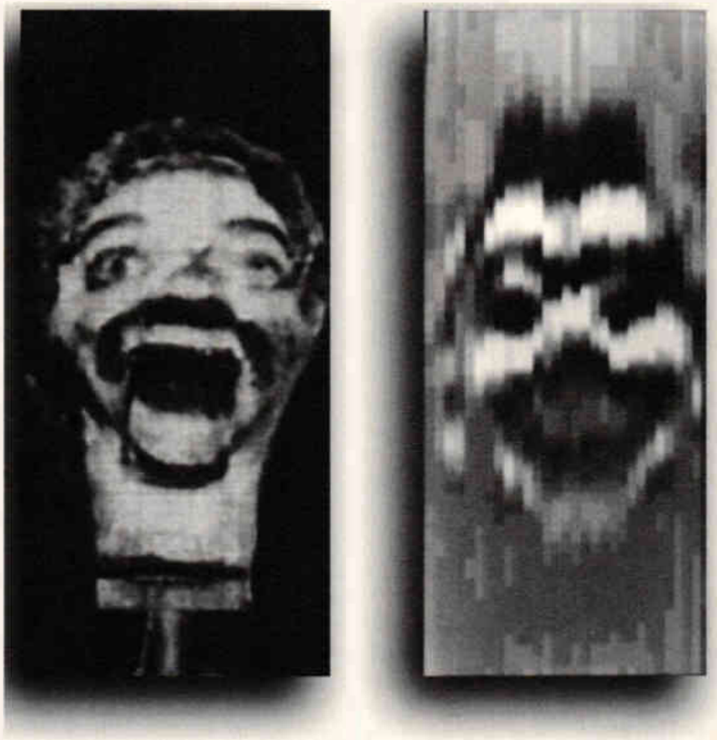


Fig. 3. Instead of live performers, Baird often used a ventriloquist's dummy head in his experiments as a test subject. He had several such heads – all called 'Stookie Bill'. The photograph on the left is a different model from that restored from the 1927 recording on the right. The vertical line shearing is caused by errors in constructing the scanning disc, cf Fig. 4.

reports were still describing Phonovision as a "scientific curiosity".[7] From then on, Phonovision dropped out of the news.

In all that time, Baird never demonstrated *pictures* from the discs, most likely due to their poor quality.

This is supported by the various attempts over the years since then to view pictures from the discs. Analogue filtering and oscilloscope displays showed that the recorded quality was too poor to give any recognisable imagery. But by using a computer to capture, store, analyse and process the raw signal, I have managed to restore the recordings.

The recorded quality of Phonovision is so poor that Baird could not have seen the images at the quality presented here. These experimental images fall far short of studio quality. They should not be considered as typical of Baird's and the BBC's subsequent 30-line broadcasts.

Never intended for public appraisal, the discs are merely a snapshot view of his experimental period on a subject he himself deemed unsuccessful.

The re-discovery of Phonovision

Attention on Baird's other achievements and the great strides in electronic television technology passed Phonovision by. For decades, the discs were spread around the country, until the work described here brought them together and subsequently their historic value was recognised.

After many years of searching, there are today only five different vision-only recordings from Baird's experiments. They are listed in the panel.

Some of the discs have a Columbia Graphophone Company Test Record label, **Fig. 2**, indicating Columbia had been engaged in cutting and pressing the discs. Each disc has a reference number for the session and take, consistent with Columbia Graphophone Company practice, **Table 1**.

The house of Ben Clapp, Baird's first engineer, was bombed in the Second World War destroying all but one of his collection of Phonovision discs.[8] The surviving disc, SWT515-4, is the earliest-known recording of television in the world made in September 1927 – a mere twenty months after Baird's

Table 1. Details of all known Baird Phonovision discs.

Reference No.	Date	Content discovered after restoration
SWT515-4	20 Sep 1927	operator's hand and 'Stookie Bill'
RWT620-4	10 Jan 1928	over-modulated recording of 'Wally' Fowlkes' head
RWT620-6	10 Jan 1928	'Wally' Fowlkes' head in motion (marred by amplifier oscillation)
RWT620-11	10 Jan 1928	'Wally' Fowlkes' head in motion
RWT115-3	28 Mar 1928	Baird's temp, Miss Mabel Pounsford – head and shoulders

historical first demonstration.

This disc contains a test signal – a simple white bar or edge – and one of Baird's dummy heads **Fig. 3**. It is a doubly-historic disc: it was also one of a few that Baird used to transmit test signals from Ben Clapp's house in Coulsdon to New York in late 1927[9] for the Transatlantic Television experiments. Given both the distortions on the disc and its slow frame rate, it was probably used only as a readily identifiable sound to test reception.

The 'Wally' recordings of January 1928 are the earliest of a living face. The name 'Wally' is scratched on the disc surface and the image has a close resemblance to Wally Fowlkes – one of Baird's laboratory assistants.[10]

On the discs, the subject turns his head from profile to full face and looks up and down, **Fig. 4**. When he moves his head towards and away from the camera, the effect is as if there is a vertical sheet of light immediately in front of the camera.

A picture of a Phonovision disc in a July 1928 magazine is in fact the same disc as RWT115-3 dated 28 March 1928, **Fig. 5**, supporting the validity of the dates written on the disc labels. No one knew who "Miss Pounsford" was until an appeal on Channel 4 in 1993 over the restored pictures brought success.

This was now Mabel Pounsford, a temporary secretary to Baird in the twenties, **Fig. 6**.

Signal capture. The first step in restoration is to capture the raw video signal into the computer. Recorded directly onto the disc without modulation, the video signal is played back from a conventional record deck and sampled into the computer using ideally a clock extracted from the turntable rotation.

Analogue pre-processing corrects for the disc cutter's frequency characteristic (Blumlein[11]) and phase response. The digitised signal is stored in a disc file for analysis and correction.

Processing the signal. Analysing the video signal reveals features common to all five Phonovision discs. Every disc has exactly three 30-line tv frames, i.e. 90 lines, per revolution without either separate or combined[12] audio soundtrack.

There are no embedded synchronisation pulses. The 30-line system did not support them, relying on video content for line synchronisation and manual adjustment for frame sync. The principal idea behind Phonovision was not to rely on synchronisation from the video signal but to link the camera physically with the record platter to give an exact number of frames on each revolution of the disc. Baird obviously understood the problems caused by playback variation.

Timebase distortion. This mechanical linkage gave rise to the most serious problem plaguing the Phonovision discs – fluctuation in speed. Ironically, Baird was developing Phonovision to get round that very problem. Whereas live broadcasts would give as steady a picture as the camera generating it, a recording would be subject to minor random speed changes that would ruin a sync-less television picture.

There are three separate types of timebase distortion.

Offsets in the start of certain lines, but constant from frame to frame, Figs 3 and 4. This distortion caused by errors in positioning the lenses on the Nipkow scanning disc. A slight circumferential error – radial errors do not show up – would give rise to an early or late start to a line.

The maximum error is 3% of line

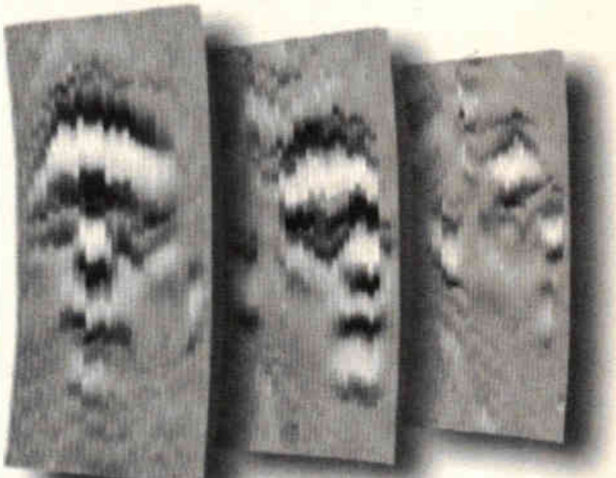


Fig. 4. From the January 1928 session, this is Wally Fowlkes, one of Baird's assistants and commonly televised as a test subject. The name 'Wally' was scratched on the disc surface.

Fig. 6. Mabel Pounsford is pictured on the left many years after her short spell as a temp to Baird. The label on the disc incorrectly says "Woman smoking a cigarette". The 'cigarette' is, in fact, her chin suffering massive timebase distortion. Restoration converts her to a non-smoker (right).

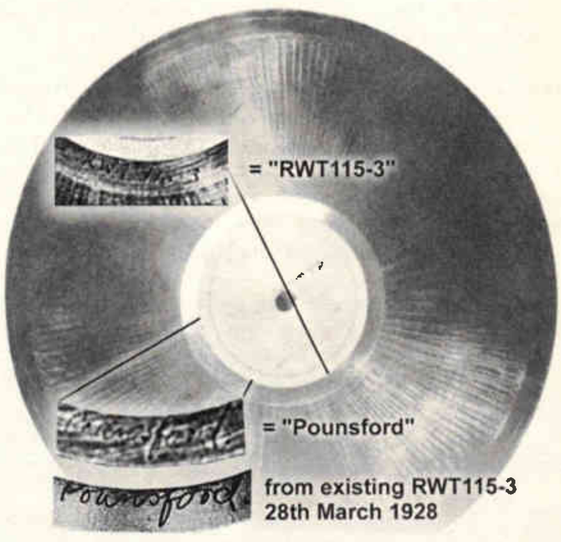


Fig. 5. Proof of the discs' ages comes from a photograph from July 1928 from which the signature "Miss Pounsford" and the serial number "RWT115-3" can be read. The current Phonovision disc dated 28 March 1928, bottom left, has identical markings.

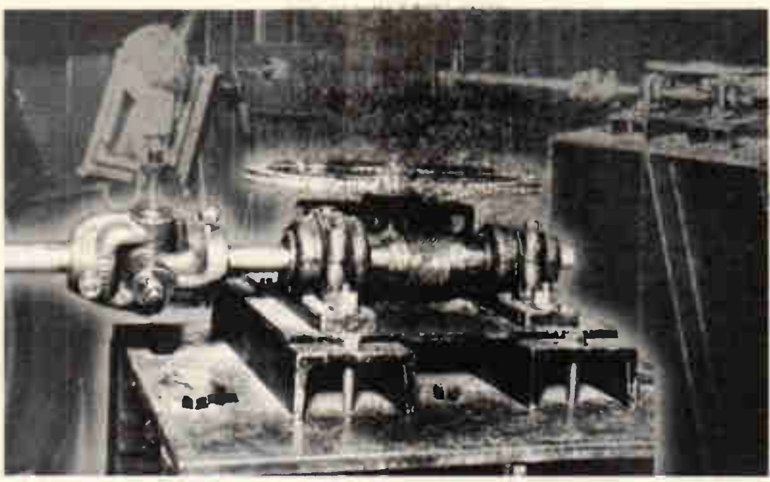


Fig. 7. This composite photograph shows the main Phonovision transport with helical gear assembly and universal joint coupling. A major component of the timebase distortion can be attributed to such a coupling.

length for line 11. indicating a 0.4° error in its position. For a 150cm-diameter Nipkow disc, this amounts to a 4mm offset error in drilling the hole for the 6cm wide lens. Notably this pattern of offsets is common to the September 1927 and January 1928 recordings indicating the same scanning disc was used for both sessions.

Low frequency variation in timebase at frequencies up to the frame rate. The effect is worse in the September 1927 recording, improves by January 1928 and is absent from the March 1928 recording. This indicates where Baird was focusing his effort.

The slow variation suggests a flexible coupling, most likely at the motor driving the Nipkow disc. A spectral analysis of the timebase errors shows an unusually high content at the second harmonic of the tv frame rate 180° phase-shifted to the fundamental.

An off-axis universal joint coupling such as in **Fig. 7** would give such a result. A bent or misaligned drive shaft would give the same effect.

High frequency variation within frame. Present only on the March 1928 recording, the pattern establishes in the first few seconds and then remains static throughout. As the pattern is at the tv frame rate, this is likely to be the result of mechanical resonance in the coupling between the Nipkow disc and the gearing assembly.

The lack of low-frequency variation apparent in the earlier discs indicates Baird had moved to a hard mechanical linkage between Nipkow disc and recording deck. This is undoubtedly the reason for this resonance.

Restoring the timebase

The absence of any synchronising information in the video signal means that correction has to rely on video content. With no low frequencies and limited video bandwidth, the Phonovision signal resembles a modulated sine wave. This makes the restoration of the timebase a complex process.

Over the years I have developed a hybrid solution based on several multi-pass algorithms using variants on auto-correlation.[13] The parameters for the algorithms are tuned to the Phonovision session on which the disc was made.

Recording speed. To make these recordings, Baird dropped his tv frame rate from 12.5 per second to around 4 per second to give about 80rev/min at the disc cutting equipment. The Columbia engineers probably dictated this rate.

Three clues support this. The first is a sequence of 11 frames in which the subject turns from face-on to the right and then to the left. **Fig. 8**. This speed is unnatural at Baird's standard of 12.5 frames per second.

The second clue is the absence of low frequencies. Recording at 80rev/min would give a line frequency of only 120Hz with may contribute to this effect.

The third clue is that the quality of the recording groove is excellent, suggesting a recording speed of 78 to 80rev/min.[14]

In his laboratory, Baird would have had extreme difficulties seeing any picture at this low frame rate, as his display had no persistence.

Signal problems

The discs all suffer from lack of video bandwidth. Given that these discs were professionally recorded, this is a real surprise.

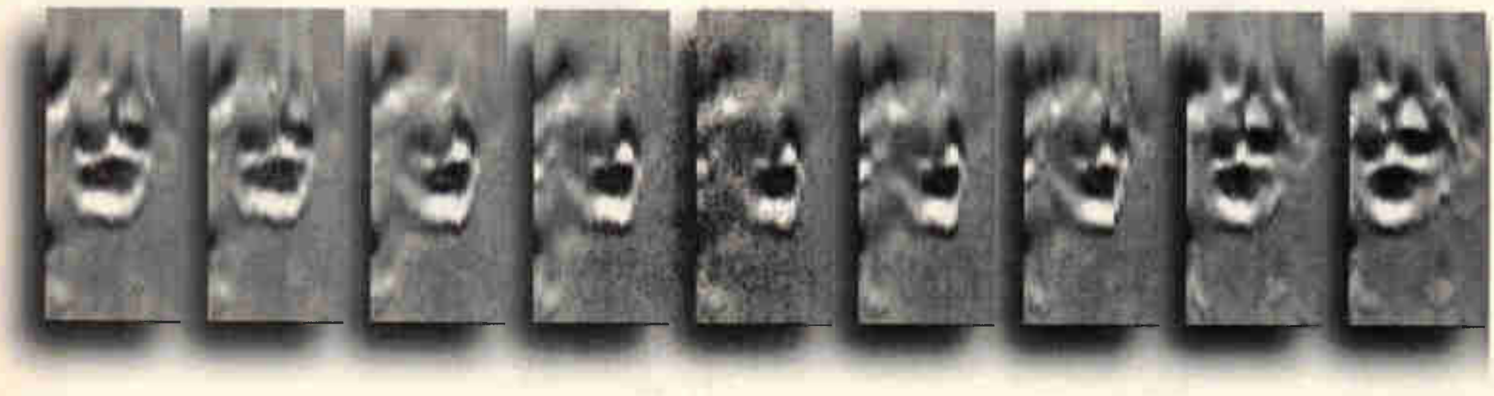
Fortunately on the earliest recording there is a bright bar or edge whose impulse response allows us to make an estimate of the system's bandwidth. The signal is reasonably flat within 1dB only between 250Hz and 1200Hz at 78rev/min.

It may be that, as shown on his 1926 patent, Baird used a microphone in front of a loudspeaker rather than a direct connection. The Columbia engineers may well have insisted on some such arrangement. That the disc-cutter has managed to record the mechanical rumble from the Nipkow disc but not the low video frequencies shows that the low frequencies were lost *before* recording.

Image processing. The unusual nature of the video amplitude distortion required me to develop a custom suite of image processing tools. Digital filtering tackled the frequency and phase errors while a time-domain image tracking algorithm reduced image noise.

Drop-outs and clicks were removed by a new algorithm based on statistical comparison of adjacent lines and frames. The restored images were re-sampled onto an arc-scan grid to sim-

Fig. 8. A series of consecutive 30-line frames showing Miss Pounsford turning her head from side-to side. The movement is too rapid for the Baird 'standard' 12.5 frames per second. This is one of the clues that the Phonovision discs were recorded at a much lower frame rate.



ulate the contemporary display method.

Ideally the images shown here should be tinted the orangey-red of neon – the variable light source used for display.

Sound and vision. At the start of each of the three discs recorded in January 1928, a rumbling sound drops logarithmically in pitch over several seconds. The profile of the drop is identical for a high-pitched shriek associated with the video content, **Fig. 9**. Notably though, the video signal maintains constant pitch throughout this period. This is a great piece of evidence telling us several things.

The shriek dropping in pitch is a sound external to the platter: the platter is coming up to speed and hence the sound appears to fall in pitch. That the video stays at constant pitch tells us that, for the January 1928 session, the Nipkow disc and record platter are mechanically linked.

A rumble at TV frame rate also drops in pitch. This is the sound of the Nipkow disc turning. The shriek is most likely Baird's video amplifier bursting into oscillation.

Analysing the graph tells us that the disc-cutter was started when the Nipkow disc had reached 20% of final speed after just over two rotations. In the following six rotations, it had achieved 50% speed and after a further 24 rotations had reached 90% of maximum speed of around four rotations per second.

Knowing the mass of the Nipkow disc, we could estimate the torque force of Baird's main drive motor.

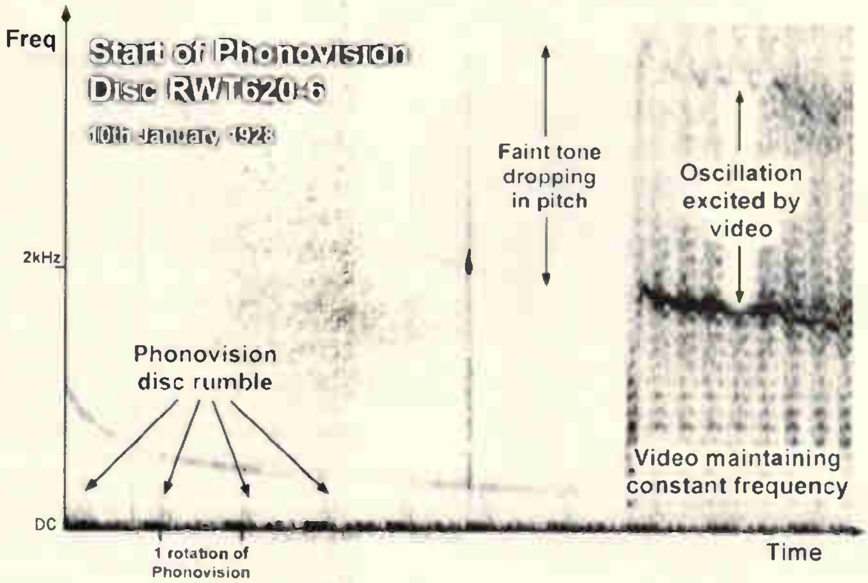


Fig. 9. A sonogram of the start of a January 1928 recording provides evidence that the scanning disc and Phonovision turntable were mechanically linked. In addition, Baird's video amplifier in oscillation – evident from the central black line – gives us the acceleration profile of his camera disc.

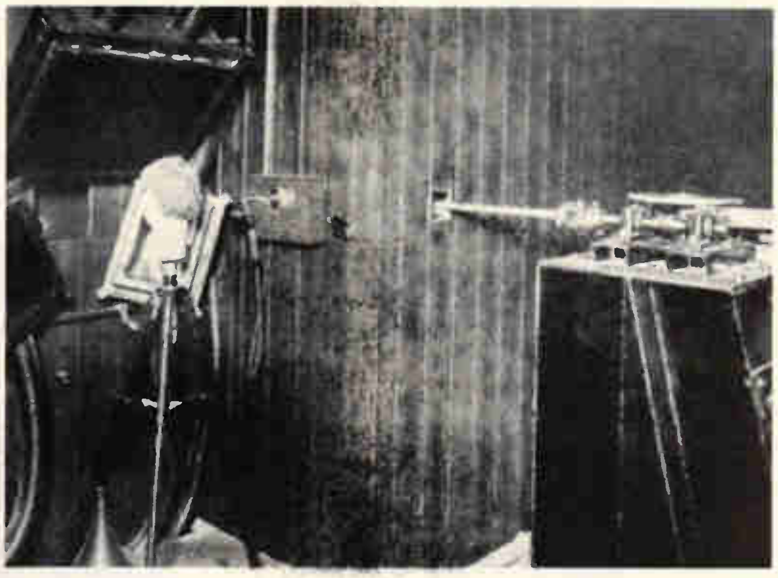


Fig. 10. This rarely seen enhanced view shows – for the first time – the same scanning equipment being used for Phonovision, on the right, and Baird's experiments in near-infra-red light which he called "Noctovision," shown on the left. Often misunderstood and overstated, Noctovision merely exploited the extended red-end response of his photo-sensor.

How Baird recorded Phonovision

A few pictures exist from publications of 1928 of Baird's Phonovision recording studio. By extracting common features in each of the pictures, I have built a computer 3D model for the laboratory.

The Phonovision disc on the turntable gives the absolute reference for dimensions. The lessons learned from the discs support the model and suggest that the studio portrayed could well have been used to make or even replay the Phonovision discs.

Underneath the record platter is a helical-gear assembly that transfers the rotation of the drive-shaft to the turntable, **Figs** 7, **10, 12**. Measuring the relative diameters of the gear parts from the photographs gives a ratio of 3:1. For every three turns of the drive shaft, there is one revolution of the record platter. This matches what we see with the Phonovision discs.

These discs all have 90 lines per revolution, so each revolution is exactly three frames. If the shaft were directly coupled to the scanning disc, then you would expect exactly three frames per revolution. Following the direction of rotation of the record platter through the gears, Fig. 12, the shaft entering the wall rotates clockwise.

On the left of the picture, Figs 10, **11**, 12, a ventriloquist's dummy head faces an aperture under blacked-out lights. In the aperture, parts of two lenses are visible, Figs 10, 12. From the computer model, for a 64cm (25in) radius Nipkow disc, the apertures would be just over 13cm (5in) apart, which is what we see on the picture.

When the disc was spinning, the lenses moved from bottom to top. This, and the drive shaft coming out to the Phonovision equipment just 64cm (25in) away, is consistent with a single Nipkow disc centred on the drive shaft.

The overall Nipkow disc would be around 1.5m (5 feet) in diameter. Although we already knew that Baird built large Nipkow discs, this is the first evidence of their use in his pioneering work[15].

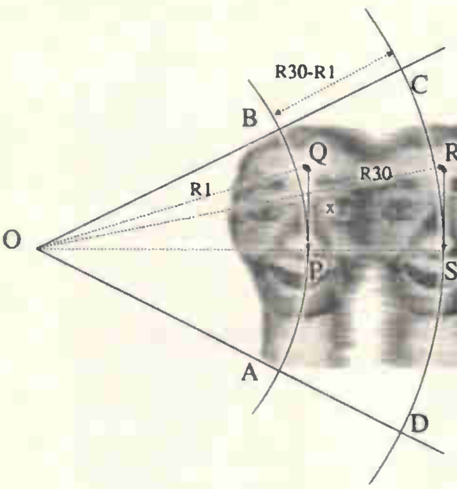


Fig. 13. By measuring the proportional height of a fixed-size object – the centre-line of 'Stookie Bill' – across all lines, we can calculate the image aspect ratio from the unique geometry of arc-scanning.

Fig. 14. This is a plot for all positions of 'Stookie Bill' head as the operator rocks it back and forth. Regression analysis gives us the smoothed values from which we can calculate the aspect ratio.

Arc scanning and aspect ratio

Part way through the earliest Phonovision disc of 'Stookie Bill' – Baird's ventriloquist's dummy head – a hand rocks the head from side to side across all lines in the picture. This good fortune allowed me to use the fixed height of the head to determine whether the camera system was a Nipkow disc or a mirror drum.

A mirror drum generates an image with straight lines whereas a Nipkow disc scans each line in an arc. For the Nipkow disc, an object of constant height moving across the field of view takes proportionately more of the line length the closer it is to the centre of rotation, **Fig. 13.**

Using the centre line of 'Stookie Bill', I measured the proportion of line length across all possible positions and then plotted on a graph. The geometry of arc-scanning allows the aspect ratio of the image to be calculated.[16]

Aspect ratio from arc-scanning. In Fig. 13, ABCD represents the scanned area on the Nipkow disc with angle AOB being $2\pi/30$ – assuming a single spiral per revolution. AB and CD are the paths followed by lines 1 and 30 respectively. For small angles, the object Heights at these extremes are:

$x/R_1=\sin f$
$y/R_{30}=\sin g$

where f is angle POQ, or $F_1 \times 2\pi/30$, g is angle SOR, or $F_{30} \times 2\pi/30$) and F_1 and F_{30} are the fractions of line length for the respective lines derived from the regression analysis, **Fig. 14**.

For constant object height across the frame, $x=y$, and you can combine the equations to derive an expression for the width, W, of the image:

$$W=R_{30}-R_1=R_1\times(a-1)=-R_{30}\times(1/a-1)$$

where $a=\sin f/\sin g$. Now, the raster height can be expressed b y the arc-length, H,

$H_1=R_1\times 2\pi/30$
$H_{30}=R_{30}\times 2\pi/30$

Aspect ratio AR is defined as the ratio of height to width of the scanned area, or the average of the instantaneous aspect ratio values on lines 1 and 30.

$$AR=-\pi\times((1+a)/(1-a))/30$$

Using F_1=0.36037 and F_{30}=0.32644 from Fig. 14 gives AR=2.12:1

Taking into account the action of rocking the head, the calculated aspect ratio is 2.12 in mid-frame, within 10% of the actual 2.33 ratio, i.e. 7 vertical to 3 horizontal.

Early standard.

There is one departure from the subsequent Baird standard for 30-line television: the first line in the frame was innermost on the disc on the Phonovision discs whereas the standard called for the first line to be the outermost. With Miss Pounsford's hair parting determining scanning direction, Baird's camera used for Phonovision scanned the frame of the scene from left to right rather than the Baird standard of from right to left.

The 'standard' though is for the broadcast period that started in 1929. Baird's television standards had been migrating over the years: his first demonstration in January 1926 had been on 32 lines[17]. With the Phonovision discs we have evidence of early use of the 30-line system with only minor differences from the subsequent broadcast standard.

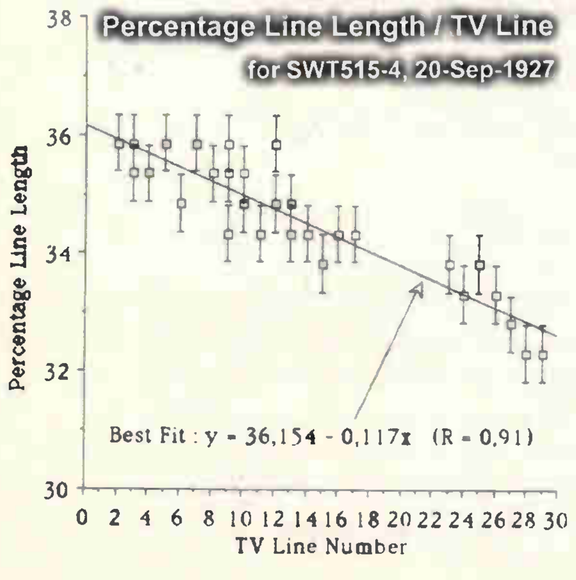
The Phonovisor

Intended as a mass-market replay device, the Phonovisor was stunningly simple in concept. By mounting the disc turntable of a conventional gramophone onto a Nipkow disc, synchronised playback of pictures through the Nipkow disc would be assured without recourse to electronics or complex mechanics, **Fig. 15**.

The practicalities however make it a challenge, despite the problems in making Phonovision discs.

There is a trade-off between replay rate, number of frames per revolution and displayed picture size. A Phonovisor used to view Phonovision needed a playback speed of 250rev/min to give a Baird television standard picture.

Not only is needle replay not practical at this speed, but the recording is less than a minute long. The viewable picture height on a Baird Nipkow disc is the arc-length between adjacent holes.



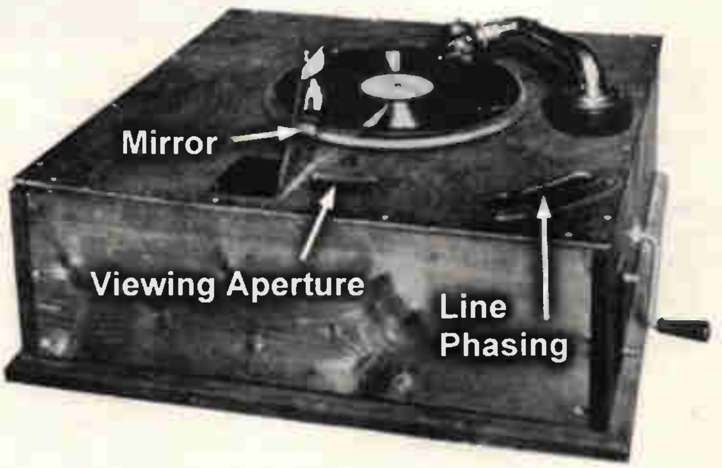


Fig. 15. Mock-up of Baird's Phonovisor showing what he intended to manufacture. Note that the pick-up is mounted backwards. The lever on the right may be either for lining up the image on replay or more simply for adjusting speed.

On a Phonovisor with a 50cm disc, like Fig. 15, the image would be about 17mm by 7mm. It would be proportionately smaller the more frames per revolution.

In summary

Starting from simply the pattern and content of a vision signal cut onto a handful of audio test discs, I have been able to reveal an astonishing amount of detailed new information from these historic pioneering days of television.

The main achievement has been the restoration of what I believe are the world's earliest recordings of television. Television pictures captured in Baird's laboratory in the twenties must be rated among the most important of television's short history.

While the restoration work reveals the latent images, analysis of the content and the corrections applied reveals a wealth of hard facts about Baird's experiments. We now know what type of camera Baird was using, how well it was built, how fast it accelerated to speed, what departures there were to his television standard – even the type of lighting in the studio.

Most importantly, we can now truly appreciate the difficulties he encountered in trying to bring this invention to practicality.

Baird himself summed it up. "...I had a gramophone record made of... (the vision signal) and I found that... I could reproduce the original scene. A number of these records were made... but the quality was so poor that there seemed no hope of competing with the cinematograph."[18]

Finally, I would like to mention that I am indebted to Ray Herbert, ex-employee of Baird and now the Baird Company historian, for his support over the years. ■

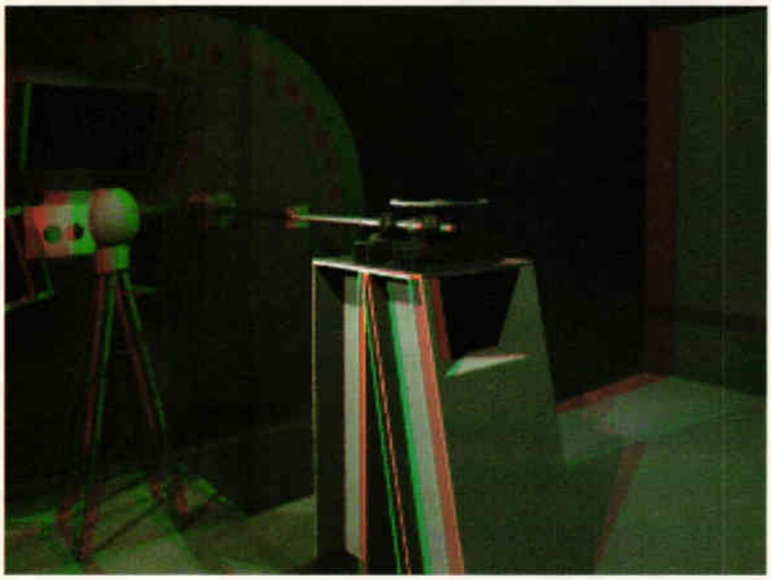


Fig. 11. A stereo anaglyph, requiring red-blue spectacles, of the computer reconstruction of Baird's laboratory, cf Fig. 10.

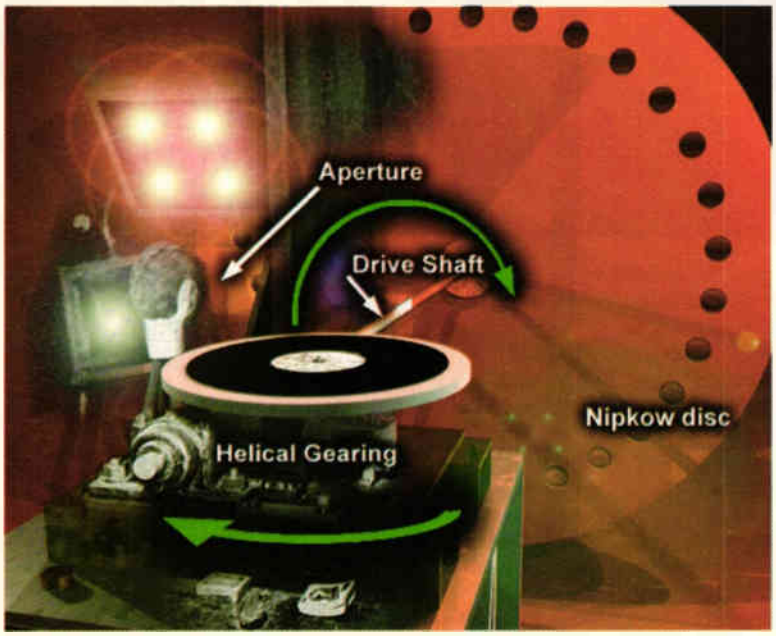


Fig. 12. Knowing the direction of rotation of the turntable from the discs, and following this action through the helical gears, Fig. 7, you can see that the drive-shaft rotated clockwise as it entered the wall. Behind the wall is the most likely arrangement of a large diameter Nipkow scanning disc.

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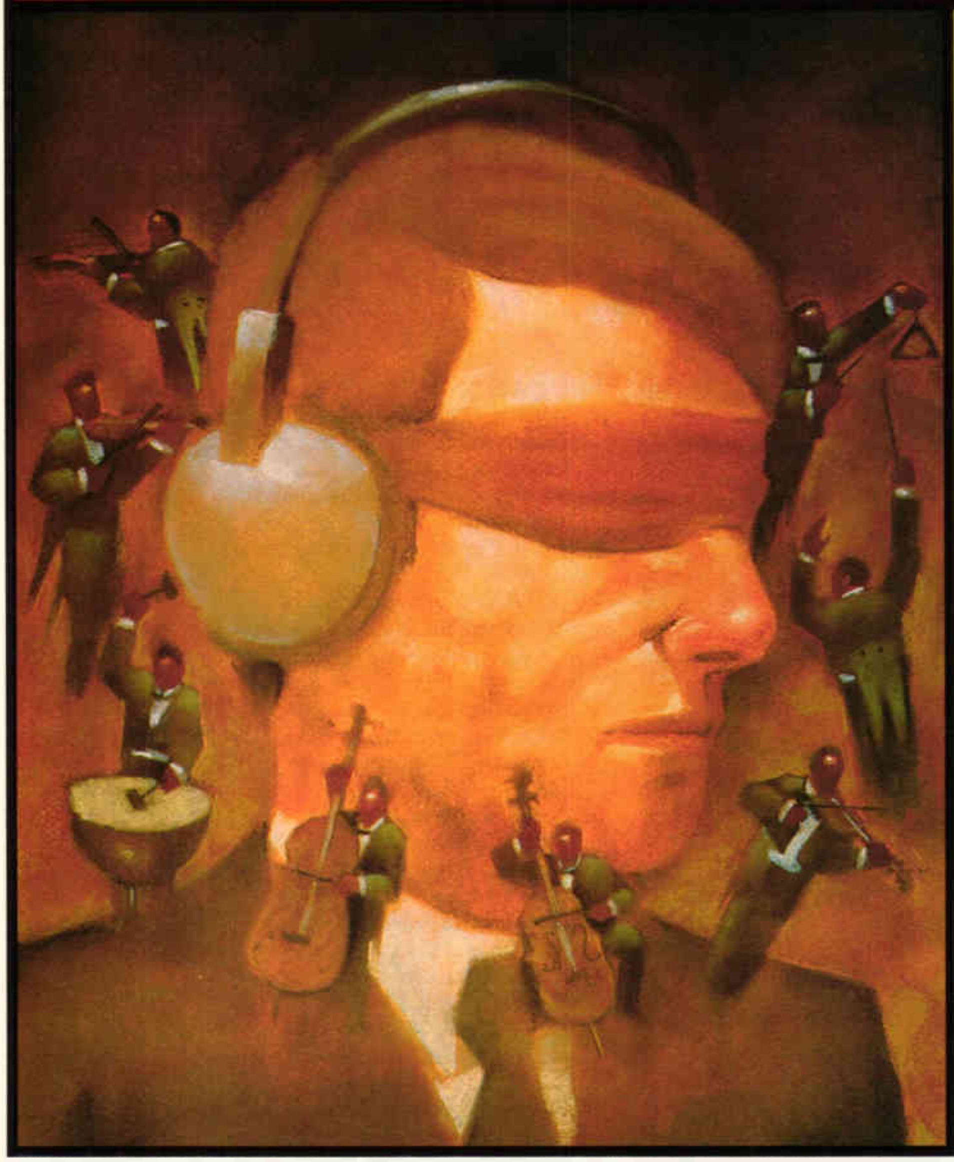
Improve your image



Now that stereo audio designers have all but eliminated crosstalk, Richard Brice explains why they shouldn't have. Richard also builds on Blumlein's work, presenting an improved stereo microphone technique, in this first article based on his new book.

Electronics plays two roles in the art-form we call music. Traditionally, its role is regarded as the conduit and its aspiration, the unimpeachable conveyer of music.

Many articles have appeared in these pages which discuss this role; the quest for the ever-more 'perfect' audio amplifier for example. But I'd like to take a different approach which takes a look at the creative role for electronics. Scrutinised from this perspective, what is in my view a rather moribund debate takes on a new vitality.

A perfect example of this more open-minded approach, concerns improvements to conventional stereophony. This article concentrates on just two techniques which aim to improve conventional stereo recording techniques;

- an unusual stereo microphone arrangement
- a very simple idea for improving two-loudspeaker stereophonic image quality.

A better image

Postponing the microphone technique until later, let's first look at a system which uses an apparently 'distorting' crosstalk signal to improve stereo quality. The irony here illustrates well the enlightened approach mentioned above.

For years, the reduction of left-right crosstalk has been a primary aim of recording system designers and one of the 'triumphs' of digital audio mooted as its elimination. But we now know that there are beneficial effects of controlled left-right channel crosstalk. So, the effects of this 'distortion' have been misunderstood and the deleterious results from its elimination in digital systems similarly mistaken.

It is possible that this has nurtured much of the debate surrounding the subjective differences between analogue and digital recording systems. It also explains many of the apparent 'shortcomings' of digital recording. In order to see why, we have to take a quick look at our ability to localise – i.e. determine the direction of – sounds in space.

How we locate sounds

Consider the situation in **Fig. 1**, where an experimental subject is presented with a source of steady sound located at some distance from the side of the head. The two most important cues the brain uses to determine the direction of a sound are due to the physical nature of sound and its propagation through the atmosphere and around solid objects.

Two reliable observations can be made:

- at all frequencies, there is a delay between the sound reaching the near ear and the further ear,
- at high frequencies, the relative loudness of a sound at the two ears is different since the nearer ear receives a louder signal compared with the remote ear.

It can be demonstrated that both effects aid the nervous system in its judgement as to the location of a sound source. At high frequencies, the head casts an effective acoustic 'shadow.' This shadow acts like a low-pass filter and attenuates high frequencies arriving at the far ear. In this way, it enables the nervous system to make use of intensity differences to determine direction.

At low frequencies, sound diffracts and bends around the head to reach the far ear virtually unimpeded. So, in the absence of intensity-type directional cues, the nervous system compares the relative delay of the signals at each ear. This effect is termed interaural delay difference.

In the case of steady-state sounds or pure tones, the delay manifests itself as a phase difference between the signals arriving at either ear. But, of course, this phase difference is only useful at low frequencies. Above about 500Hz, the distance between the ears is more than one wavelength.

The idea that sound localisation is based upon interaural time differences at low frequencies and interaural intensity differences at high frequencies has been called 'duplex theory' and it originates with Lord Rayleigh at the turn of the century.

Two-loudspeaker stereophony

Consider the 'classic' stereo arrangement, **Fig. 2**. A moment's thought will probably lead you to some fairly obvious conclusions: if all the sound comes out of the left loudspeaker, the listener will clearly experience the sound from the left. Similarly with the right.

If both loudspeakers reproduce identical sounds at identical intensity, it is reasonable to assume that the listener's brain will conclude the existence of a 'phantom' sound, coming from directly in front. This is because, in nature, that situation will result in the sound at both ears being identical. And indeed it does; as experiments have confirmed.[1]

More surprisingly, proportionally varied interchannel signal intensities result in a continuum of perceived 'phantom' image positions between the loudspeakers. And the system works as well for high frequency sounds as for low frequency ones. But how?

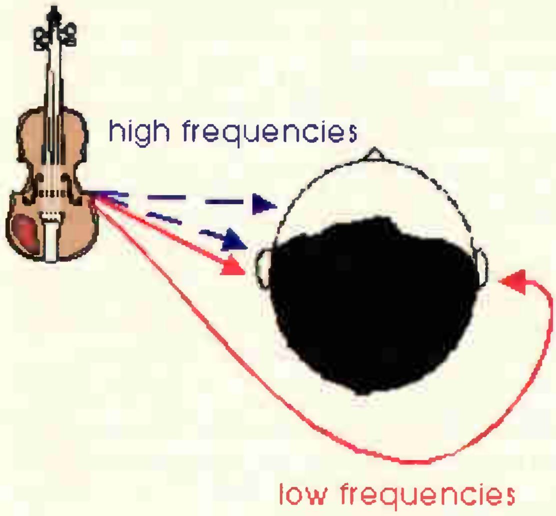


Fig. 1. Two key cues that the brain uses to locate sound sources are the difference in time taken to reach each ear and, at high frequencies, the intensity of sound reaching each ear.

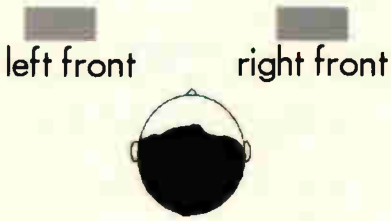


Fig. 2. It is easy to understand how the classic stereo arrangement works with high frequencies, but what about the lower frequencies, where the sound can diffract around the head and reach the other ear?

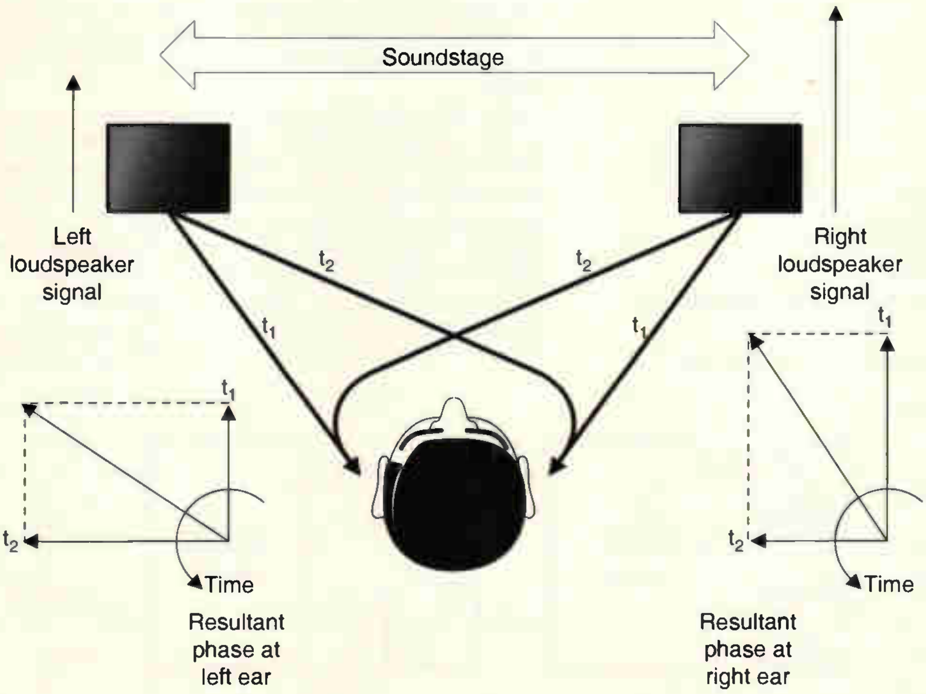


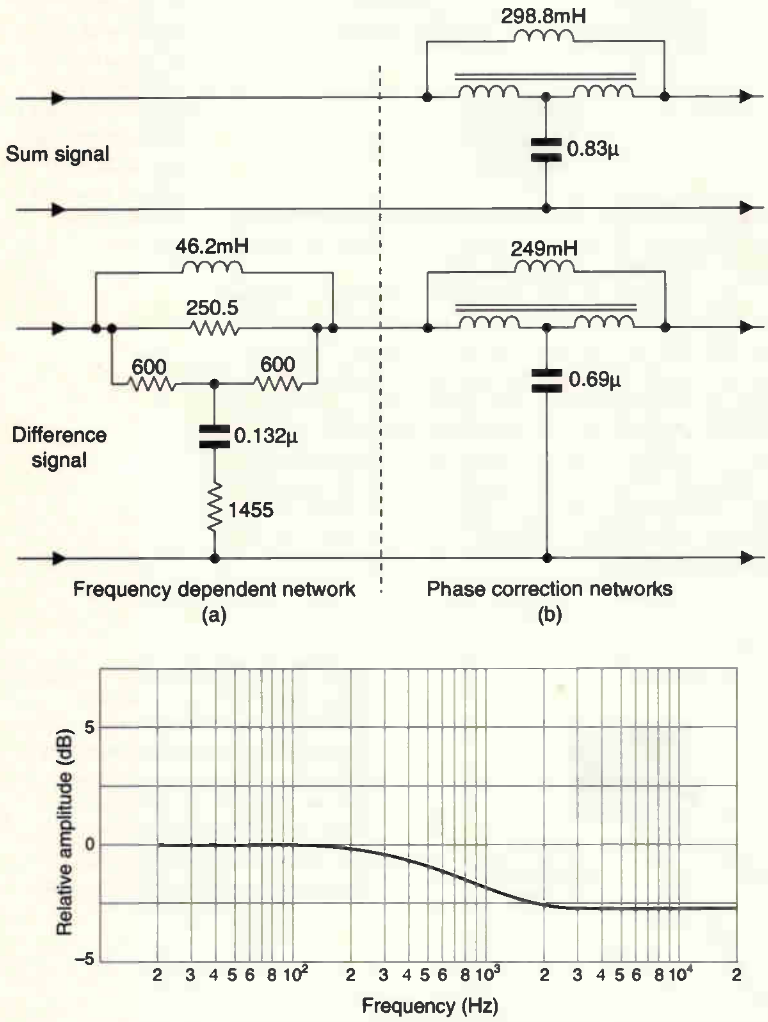
Fig. 3. While it is immediately obvious that left/right channel intensity differences result in high-frequency inter-aural intensity differences when listening to a stereo loudspeaker system, it is far from obvious that these same level differences do, in fact, translate into low-frequency interaural phase differences as well.

While it is fairly obvious that inter-channel intensity differences will reliably result in the appropriate inter-aural intensity differences at high-frequencies, what about at low-frequencies? Here, the sound can diffract around the head and reach the other ear. Where does the necessary low-frequency time-delay component come from?

Well, when two spaced loudspeakers produce identically phased low-frequency sounds at different intensities, the sound-waves from both loudspeakers travel the different distances to both ears and arrive at either ear at different times.

Figure 3 illustrates the principle. The louder signal travels the shorter distance to the right ear and the longer distance to the left ear. But the quieter signal travels the shorter distance to the left ear and the longer distance to the right ear.

The result is that the sounds add vectorially to the same intensity but with a different phase at each ear. Our brain interprets this phase information in terms of interaural delay. This means that stereophonic reproduction from loudspeakers requires only that stereo information be carried by interchannel intensity difference.



Confused literature...

Despite a huge body of confused literature to the contrary, there is no requirement to encode interchannel delay difference. If this were not the case, the pan control, which the sound engineer uses to 'steer' instruments into position in the stereo sound-stage would not the simple potentiometer control shown in **Fig.** 4.

You might think that it is incredibly fortunate that a given interchannel intensity ratio, leading to a particular interaural intensity ratio at high frequencies, causes an exactly appropriate interaural phase difference at low frequencies. It would be incredibly fortunate – if it were true.

For a given interchannel intensity difference, the direction of the perceived auditory event is further from a central point between the loudspeakers when a high-frequency signal is reproduced than when a low frequency is reproduced. Since music is itself a wideband signal, when two-loudspeakers reproduce a stereo image from an interchannel intensity derived stereo music signal, the high frequency components of each instrument or voice will subtend a greater angle at the listening position, than will the low-frequency components.

In fact the stereo image will be 'smeared.' There exists an analogy with chromatic aberration in a lens. This problem was appreciated even in the very early days of research on interchannel intensity related stereophony and, through the years, a number of different solutions have been proposed.

The shuffler

In his original stereo patent application, Blumlein mentioned that it was possible to control the width of a stereo image. He explained that this could be done by matrixing the left and right signal channels into a sum and difference signal pair and controlling the gain of the difference channel prior to re-matrixing back to the normal left and right signals.

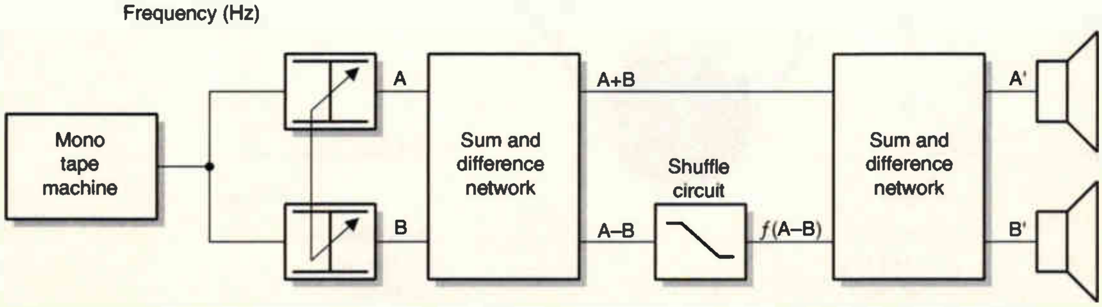
Blumlein further suggested that, to alter the stereo image width in a frequency dependent fashion, all that was needed was a filter with the appropriate characteristics to be inserted in this difference channel. After his untimely death, the post-war team working at EMI on a practical stereo system and attempting to cure this frequency dependent 'smearing' of the stereo picture implemented just such an arrangement and introduced a low-pass filter into the difference channel.[2]

Figure 4 is an illustration of their practical Shuffler circuit – as they termed it – and its implementation in the difference channel. Unfortunately this circuit was found to introduce distortion and tonal colouring and was eventually abandoned.

Other derivatives of the Shuffler have appeared using operational amplifier techniques. But the act of matrixing, filtering and re-matrixing is fraught with problems. This is because it is necessary to introduce compensating delays in the sum channel. These must exactly match the frequency dependent delay caused by the filters in the difference channel if comb filter colouration effects are to be avoided.

Moreover, the signal manipulation performed by the Shuffler must be very carefully defined and the EMI team did not have the benefit of more modern psychological

Fig. 4. Practical shuffler circuit and its implementation in the difference channel.



research into the signal manipulation required to bring about stereo-image improvement.

Edeko

Remember, it's a fundamental characteristic of the blurring problem that the brain perceives the high-frequency intensity derived image as generally wider than the low-frequency, delay-derived image. With this in mind Dr Edeko[3] conceived of a way of solving the problem acoustically and therefore of side-stepping the problems which beset electronic solutions.

Edeko suggested a specially designed loudspeaker arrangement, **Fig. 5**. In this arrangement, the angle between the high-frequency loudspeaker drive-units subtended a smaller angle at the listening position than the mid-range drive-units. In turn, the mid-range drivers subtended a smaller angle than the low frequency units.

This device, coupled with precise designs of electrical crossover network, enabled the image width to be manipulated with respect to frequency.

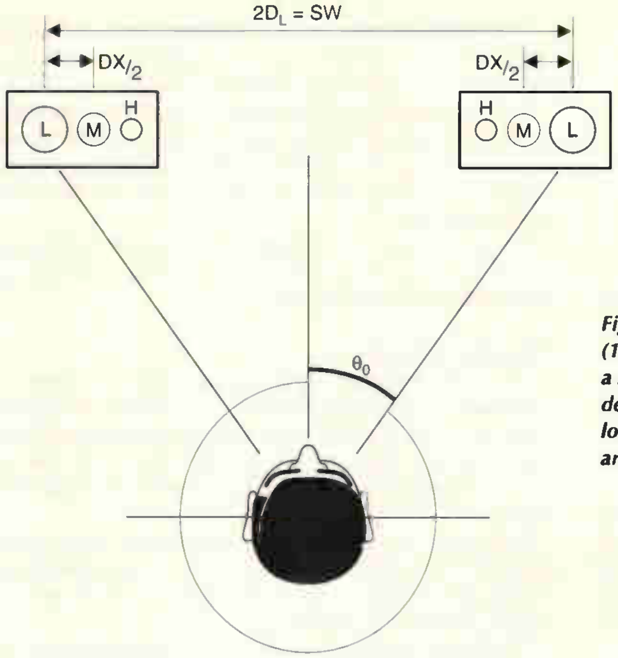


Fig. 5. Edeko (1988) suggested a specially designed loudspeaker arrangement.

Sharper images using crosstalk

There is a much simpler technique which may be used to narrow a stereo image at high frequencies and that is by the application of periodic interchannel crosstalk.[4]

Distortion mechanisms in reproduction from vinyl and other analogue media are predominantly hf crosstalk caused by electrical or mechanical negative reactances. Interestingly, investigations reveal that these distortions may be similar to those required to bring about an improvement in the realism of the reproduced stereo image.

This suggests that there may be something in the hi-fi cognoscenti's preference for vinyl over cd and for many recording musicians' preference for analogue recording over the, apparently better, digital alternative. But the reason is not, as they invariably suppose, due to digital taking something mysteriously away. It is due to the analogue equipment adding beneficial high-frequency crosstalk distortion.

This hf crosstalk technique is exploited in the *Francinstien* range of stereophonic image enhancement systems.

In blind listening tests conducted with 'expert' audiences of musicians and recording engineers using material specially recorded for the experiment, preference for *Francinstien* enhanced signals was overwhelmingly significant.[5]

These tests were scored using classic questionnaire type Likert scales, but room was also given for comments and typical observations included, "more air" and "more space" around each instrument. This is typical of my experience of listeners' reactions to the process.

Commercial units are illustrated in **Fig. 6**. The schematic is given in **Fig. 7**. The *Francinstien* technique is especially useful because of its wide application. It can be used to improve all pre-existing stereo recordings and may thereby be left in-circuit all the time.

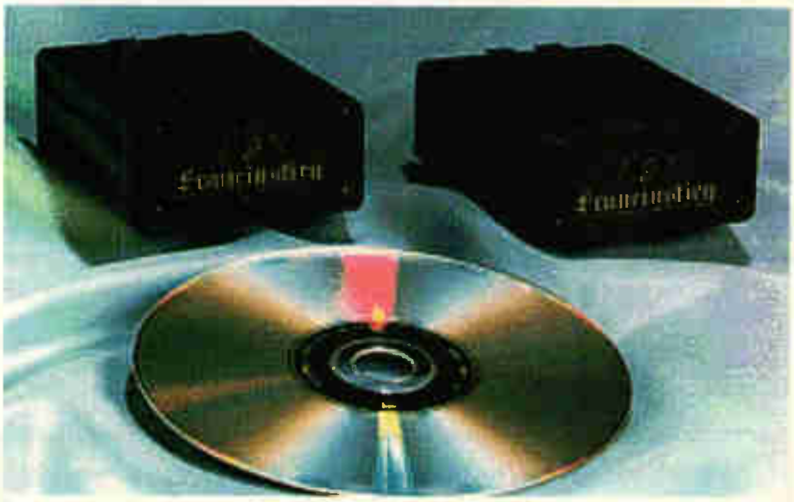


Fig. 6. Stereophonic image enhancement products incorporating beneficial hf crosstalk.

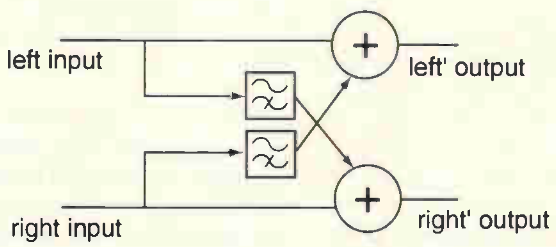


Fig. 7. Outline diagram of the stereo image enhancement circuit used in the products of Fig. 6.

Improved microphone technique

In commercial classical music recordings, it's theoretically possible to 'mike-up' every instrument in an orchestra and then – with electronic panning – create a stereo picture of the orchestra. But this is usually not done for several reasons.

Firstly, the technique is costly and complicated. Secondly often it is simply not practicable. The fact that a multi-miked stereo technique would not work for a recording of the dawn chorus goes without saying. Finally, this 'multi-miked' technique has rarely found favour when it has been tried. Critics, musicians and audiophiles all agree that it fails to provide as faithful a representation of the real orchestral experience.

For these reasons, recordings of real sound fields depend almost exclusively on the application of simple, or 'purist' microphone techniques where the majority of the signal that goes on to the master tape at a classical recording session is derived from just two microphones.

Surprisingly, there are no fixed rules as to how these main microphones should be arranged, although a number of popular deployments have evolved over the years.

The way that the microphones are arranged achieves a certain character of sound. Often it betrays a 'house style'. For instance Deutsche Grammophon currently use two pressure-zone microphones taped to huge sheets of Perspex. Essentially, this arrangement is essentially the same as wide spaced omni-directional microphones much beloved by American recording institutions.

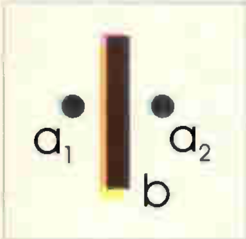


Fig. 8. In Blumlein's patent, two pressure microphones a_1 and a_2 are mounted either side of block of wood b. This wooden baffle provides the high-frequency intensity differences at the microphones in the same way as the human head affects the ears.

British record companies have developed their own arrangements too, while the BBC has stuck almost exclusively to coincident crossed pairs until relatively recently.

This part of the article describes a microphone technique which re-creates the original work by Blumlein with modern signal processing. In controlled recording and listening tests with musician-engineers, the system was preferred to other microphone techniques.[5]

It is possible this is as a result of the system recording extra directional cues over and above those coded in conventional amplitude derived stereophony.[6]

Blumlein's stereo

What makes Blumlein's 1933 patent relating to stereo[7] so important is his originality in realising the principle, as explained above, that interchannel intensity differences alone produce both high-frequency interaural intensity differences and low-frequency interaural phase differences when listening with loudspeakers.

Intriguingly, Blumlein regarded the principle of pan-potted stereo as trivial. It seems that even in 1933, the principle of positioning a pre-recorded single mono sound-signal by means of intensity control was well known.

The technological problem Blumlein set out to solve was how to 'capture' the sound field; so that directional information was encoded solely as intensity difference.

Blumlein noted that a crossed pair of velocity microphones mounted at 45° to the centre of the stereo image has the technological advantage that a pure intensity-derived stereo signal may be obtained from such a configuration without the use of electrical matrixing.

His instinct proved right because this has become one of the standard arrangements for the acquisition of intensity coded stereophony. This is so to such an extent that the configuration has become associated exclusively with his name. It is often referred to as the 'Blumlein-pair', an eponymous, and somewhat incorrect label.

In fact, the greater part of Blumlein's patent is concerned with a primitive 'dummy-head', or quasi-binaural, stereophonic microphone arrangement in which,

> "*...two pressure microphones a_1 and a_2 [are] mounted on opposite sides of a block of wood or baffle b which serves to provide the high frequency intensity differences at the microphones in the same way as the human head operates upon the ears...*" **(Fig. 8)**.

Blumlein noted that, when listened to with headphones, the direct output from the microphones produced an excellent stereo effect. But, when replayed through loudspeakers, the stereo effect was very disappointing.

The transformation Blumlein required was the translation of low-frequency, inter-microphone phase differences into inter-channel intensity differences. He proposed the following technique:

> *"The outputs from the two microphones are taken to suitably arranged network circuits which convert the two primary channels into two secondary channels which may be called the summation and difference channels arranged so that the current flowing in the summation channel will represent the mean of the currents flowing in the two original channels, while the current flowing into the difference channel will represent half the difference of the currents in the original channels... Assuming the original currents differ in phase only, the current in the difference channel will be $\pi/2$ different in phase from the current in the summation channel. This difference current is passed through two resistances in series between which is a condenser which forms a shunt arm. The voltage across this condenser will be in phase with that in the summation channel. By passing the current in the summation channel through a plain resistive attenuation network comprised of resistances a voltage is obtained which remains in phase with the voltage across the condenser in the difference channel. The voltages are then combined and re-separated by [another] sum and difference process... so as to produce two final channels. The voltage in the first final channel will be the sum of these voltages and the second final channel will be the difference between these voltages. Since these voltages were in phase the two final channels will be in phase but will differ in magnitude."*

Blumlein's comments on the perpendicularity of the sum and difference vectors are far from obvious. But consider **Fig. 9**.

A modern practical implementation

The circuit described below is designed so that maximum stereo obliquity is achieved when the inter-microphone delay is 500µs. Other calibrations are possible *mutatis mutandis*. **Table 1** tabulates the phase-angle which 500µs represents at various frequencies.

Consider the 30Hz case. The circuit operates by first deriving the sum and difference of the phasor (vector) quantities derived from the primary left and right channels. ie, let,

V_1=(0,1)

and,

V_2=(sin5.4°,cos5.4°)=(0.1,0.996)
$V_{sum}=V_1+V_2$=(0.1,1.996),

which has a magnitude of 2.

$V_{diff}=V_1-V_2$=(–0.1,0.004)

has a magnitude of 0.1. So, at 30Hz, the difference channel is 20 times, or 26dB, smaller than sum channel's signal.

Now consider the situation at 300Hz, where

V_2=(sin 54°,cos54°)=(0.81,0.59)
V_{sum}=(0.81,1.59), magnitude=1.78
V_{diff}=(–0.81,–0.41), magnitude=0.9.

At 300Hz the signal is approximately 2 times smaller, i.e. 6dB, compared with the signal in the sum channel.

Now 300Hz is nearly three octaves away from 30Hz and the gain difference is 20dB, demonstrating that the signal in the difference channel rises by 6dB/octave. This confirms Blumlein's statement that, "for a given obliquity of sound the phase difference is approximately proportional to frequency, representing a fixed time delay between sound arriving at the two ears."

Looking now at the circuit diagram for the binaural to summation stereophony transcoder illustrated in **Fig. 10**, consider the role of the integrator circuit implemented around IC_{3a}.

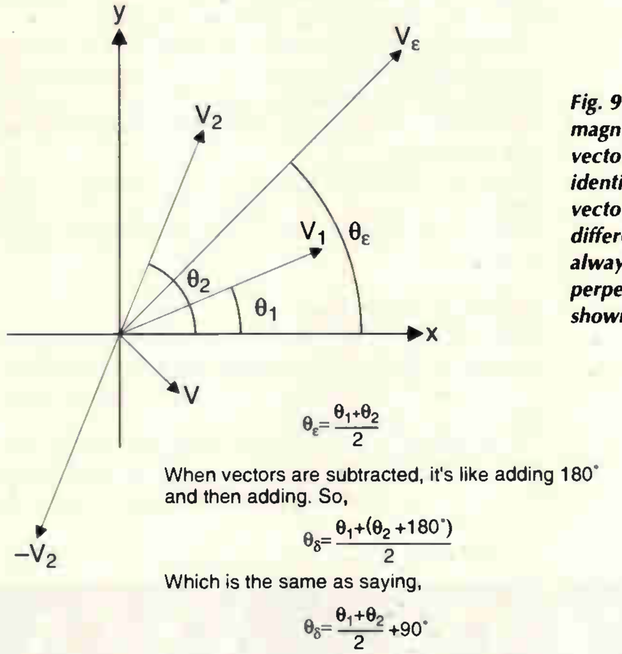


Fig. 9. Provided the magnitude of two vectors remains identical, the sum vector and difference are always perpendicular, as shown.

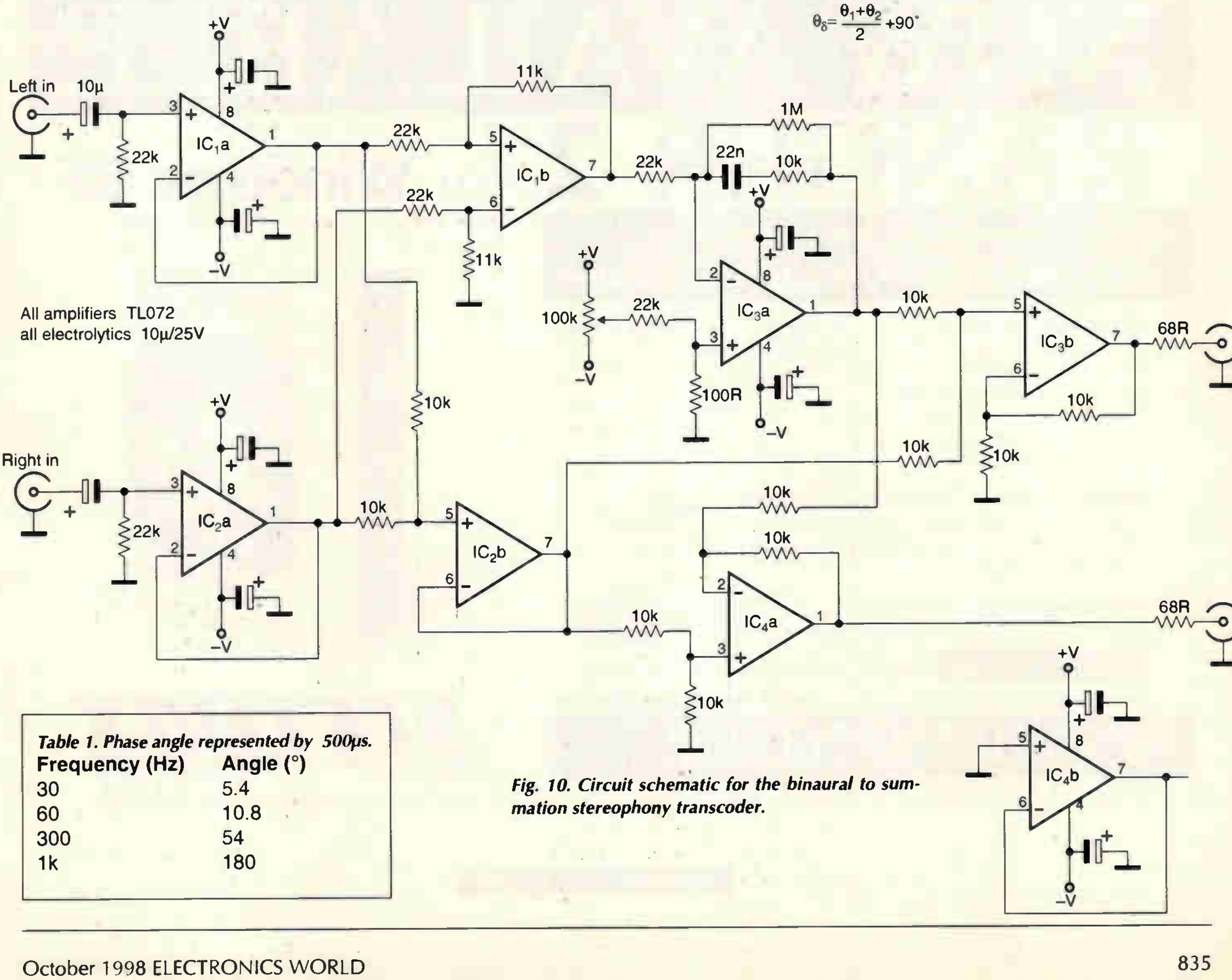


Fig. 10. Circuit schematic for the binaural to summation stereophony transcoder.

Table 1. Phase angle represented by 500µs.

Frequency (Hz)	Angle (°)
30	5.4
60	10.8
300	54
1k	180

The role of this circuit is twofold. It has to rotate the difference phasor by 90° – and thus align it with the axis of the phasor in the sum channel. It also has to provide the gain/frequency characteristic to compensate for the rising characteristic of the signal in the difference channel.

These requirements could be achieved with a simple integrator. But at frequencies above 1000Hz, it is necessary to return the circuit to a straightforward matrix arrangement. This is because the circuit needs to transmit the high frequency differences obtained due to the baffling effect of the block of wood directly into the stereo channels.

The straightforward matrix is implemented by returning the gain and phase characteristic of the integrator-amplifier to 0dB and 0° phase-shift at high frequencies. This is the function of the 10kΩ resistor in series with the 22nF integrator capacitor.

Note that the actual circuit returns to 180° phase shift at high frequencies – ie. not 0°; this is a detail which is compensated for in the following sum and difference arrangement.

Making modifications

Clearly all the above calculations could be made for other microphone spacings. For instance consider the situation in which two omnidirectional mics spaced 2m apart are used as a stereo pick-up arrangement.

With this geometry, 30Hz would produce nearly 22° of phase shift between the two microphones for a 30° obliquity. This would require a magnitude sum phasor with a value of 1.97 and a magnitude difference phasor of 0.39. In other words, an integrator with a gain of 5 is needed.

The gain at high frequency would once again need to fall to unity. At first this seems impossible because it requires the stand-off resistor in the feedback limb to remain 10kΩ as drawn in Fig. 10. A little more thought reveals that the transition region must begin at a commensurately lower frequencies for a widely space microphone system. This is because phase ambiguities of more than 180° will arise at lower frequencies. As a result, all that needs to be scaled is the capacitor, revealing that there is a continuum of possibilities of different microphone spacings and translation circuit values. ■

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The *Francinstien* range of stereophonic image enhancement systems mentioned in the article is developed by Perfect Pitch Music Ltd. Tel.. +33 1 47 23 54 02.

TELEMETRY via mobile phone

Heikki Kalliola uses a remote mobile phone to find out the temperature in his holiday cottage and turn the heating on if need be.

This telemetry solution makes use of a mobile phone and has two main benefits. It works in places where there are no telephone lines and it needs no approvals, since it requires no modifications to the telephone system.

I have applied this design to control the temperature of a holiday cottage far away in the countryside. It incorporates a talking thermometer design of mine described in an article called 'Thermometer answers back' published in the July/August 1996 issue.

Prior to setting off to the country house. I can find out what the temperature there is and switch the heating on if need be.

How it works...

Ringing sound of the telephone is caught by the microphone, amplified and converted to pulses, **Figs 1,2**. When the total number of pulses reaches the number dictated by counter IC_{11}, relay RY_1 activates solenoid *S*, the plunger of which answers the phone call.

Releasing RY_1 resets the counter and turns on the closing circuit. IC_{10}, preventing the solenoid from reacting for a couple of minutes while control commands are received.

Control is performed via dtmf, or dual-tone multiple-frequency, codes keyed from the calling phone. Tones are caught by the microphone, amplified and directed to the dtmf receiver, IC_3 and further to four digit register $IC_{4,5}$.

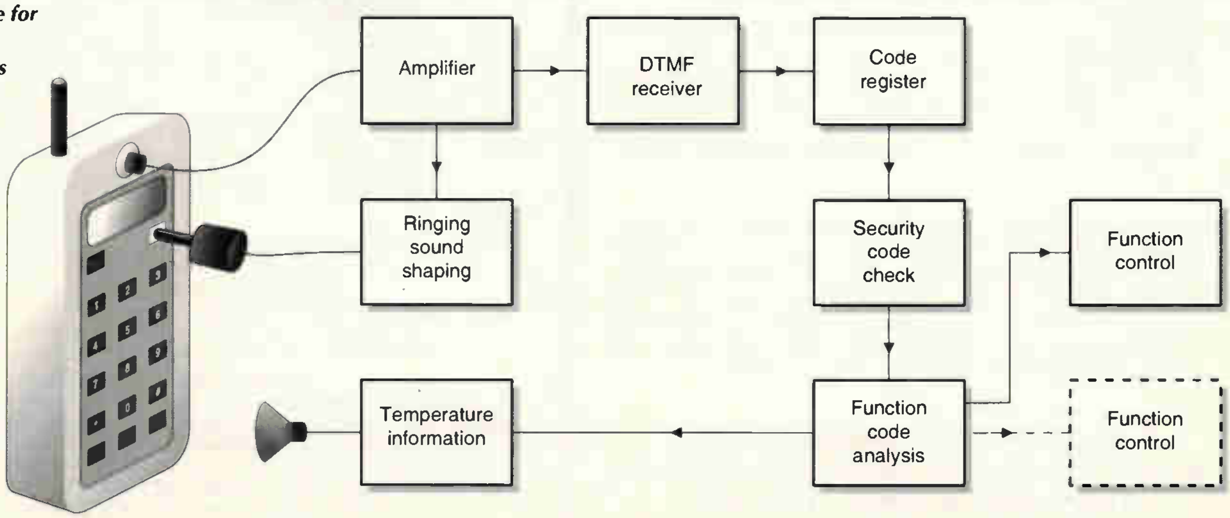
When a new digit is keyed, the previous ones shift forward. So in the diagram, the last entered digit is in the left register. Digits are converted from binary to decimal via $IC_{6\text{-}9}$. The controlling command comprises four digits, the first three forming the security code and the fourth being the function code. The valid security code can be changed any time with switches $S_{1\text{-}3}$.

When a valid four digit command has been received, the output determined by the function code is activated. With the settings shown in Fig. 2, the command '4721' triggers the thermometer to talk via delay circuit IC_{12}.

Delay is there to give the mobile phone user time to put handset back to the ear after keying the code. Command '4722' turns on an output, which I use for switching the heating. More outputs can be implemented if needed.

Output is turned off by any keying anything another than a valid control command, i.e. security code plus function code. As a result, this circuit does not allow simultaneous control

Fig. 1. Basically, the circuit listens for a call, answers it and then waits for a specific sequence of four digits. The first three digits are for security, the fourth contains command information.



of outputs independently from each other. If you turn on one channel, it turns off another which possibly has been on.

A more flexible arrangement would be easy to produce using a microcontroller.

Operational aspects

The microphone is best located near the earpiece of the phone, where the dtmf codes are received.

Sensitivity of the amplifier is adjusted via R_6. Do not set the sensitive higher than it needs to be since noise could then make the solenoid operate when it shouldn't.

The solenoid is fixed in front of the answering button, which is normally a green handset symbol. It is important not to set any legitimate numbers for the phone, otherwise disturbing noise from the environment could make the solenoid call that number.

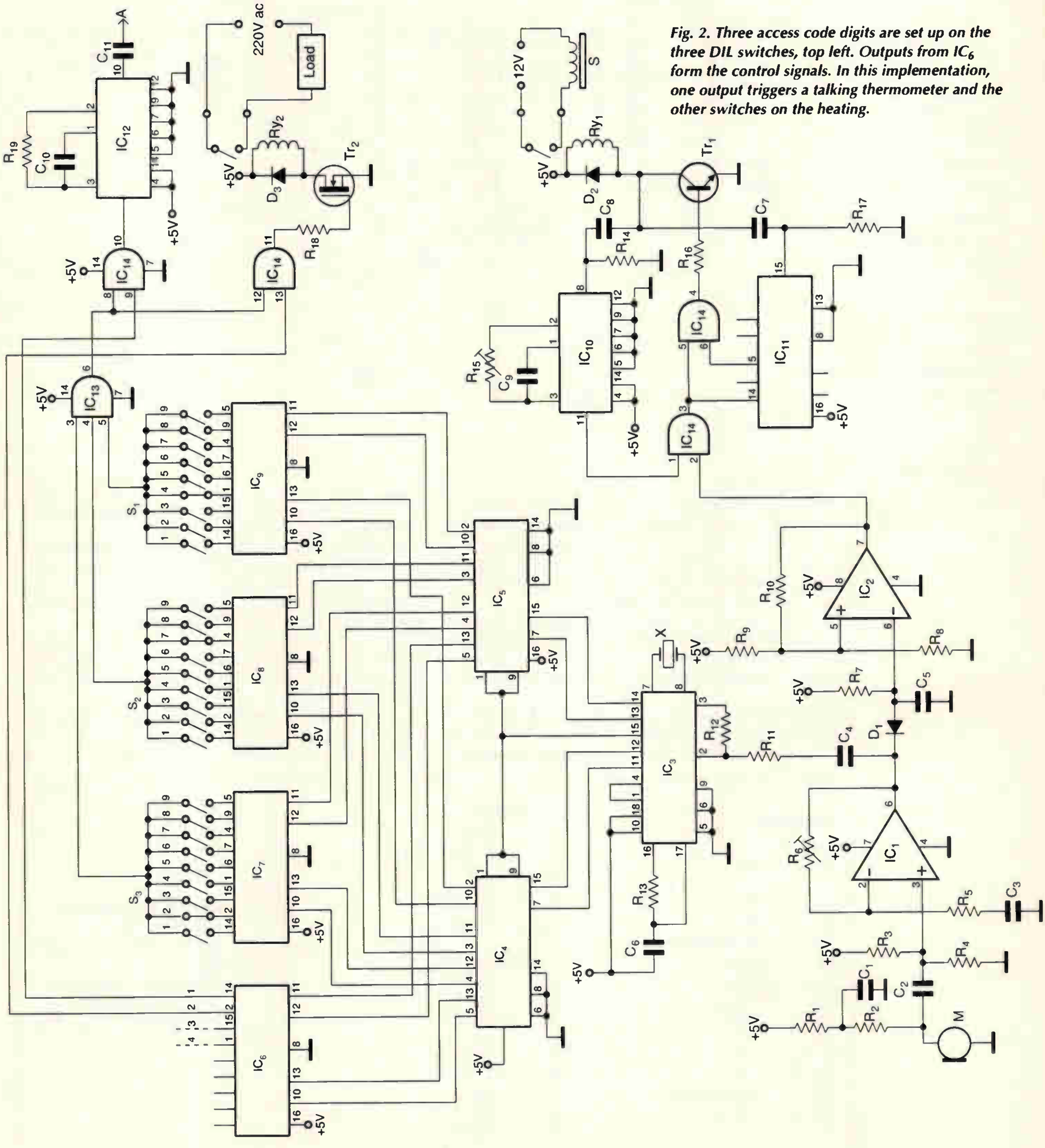


Fig. 2. Three access code digits are set up on the three DIL switches, top left. Outputs from IC_6 form the control signals. In this implementation, one output triggers a talking thermometer and the other switches on the heating.

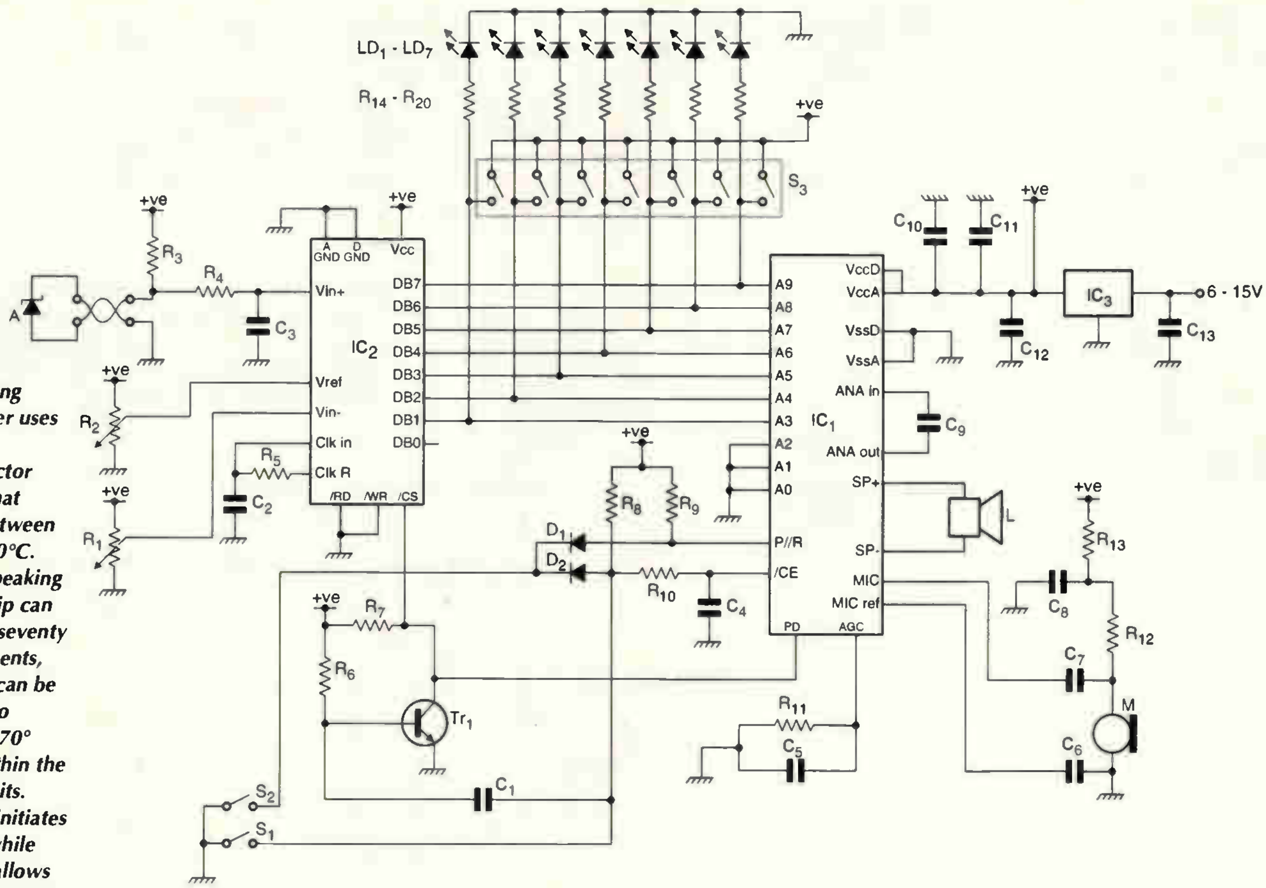


Fig. 3. Talking thermometer uses a National Semiconductor sensor IC that operates between –40 and 100°C. Since the speaking memory chip can store up to seventy announcements, the system can be calibrated to handle any 70° window within the sensor's limits. Pushing S_1 initiates playback, while holding S_2 allows recording. Point A of the main circuit connects to S_1.

The number of ringing sounds to activate the solenoid is determined by which output pin of counter IC_{11} is connected to gate IC_{14}. It is better not to let the phone answer too early to prevent solenoid activating before the telephone is ready. It sounds also more natural to the user if the phone rings a few times before answering.

Note that in this circuit the functions are mutually exclusive. If for example the heating is turned on and you send a command to the interface to listen to the temperature, the heating will turn off and stay off until re-activated.

Note also that keying anything other than the right four digit code will turn off a function that was on. This could be a useful security feature. If the correct codes are forgotten or lost, it is still possible for anyone knowing the phone number to turn off a function.

If the device is to be used in critical applications like heating, additional security controls like thermostat, timer switch, etc., should be installed . These are needed to make sure that no damage is caused in case of phone connection disturbance or a user forgetting to turn off the device.

The circuit does not contain feedback to the user verifying whether the requested function has actually been performed. Such a feature could be added by constructing a voice signal to the connecting relay.

In my application, verification is automatic, since the temperature message is verification itself. In addition, relay RY_2 is noisy enough to be audible over the phone. ■

Parts list

Resistors (0.25W)

R_1	330
R_2	1.5k
$R_{3,4}$	47k
R_5	1k
R_6	5M trimmer
R_7	5.6M
$R_{8,13}$	380k
R_9	470k
R_{10}	3.3M
R_{11}	10k
$R_{12,19}$	100k
$R_{14,17}$	33k
R_{15}	1M trimmer
$R_{16,18}$	2.2k

Capacitors (16V)

$C_{1,9}$	47μF
C_2	0.47μF
C_3	1μF
$C_{4,6\text{-}8}$	100nF
C_5	200nF
$C_{10,11}$	6.8μF

Semiconductors

IC_1	LF357
IC_2	TL072
IC_3	8870
$IC_{4,5}$	4015
$IC_{6\text{-}9}$	4028
$IC_{10,12}$	4047
IC_{11}	4017
IC_{13}	4073
IC_{14}	4081
Tr_1	2N2222
Tr_2	IRFZ34
$D_{1\text{-}3}$	1N4001

Other

M	Electret microphone
RY_1	DIL-relay (5V)
RY_2	Relay (5V, contacts 10A, 220V)
$SW_{1\text{-}3}$	DIL-switch (9 contacts)
X	3.579545Mhz crystal
S	Solenoid 12V (eg. RS 347-652)

Designing with saturation

In order to get the best out of a switching design involving transistors that saturate, you need to have a sound knowledge of the characteristics of saturation. Bryan Hart illustrates why.

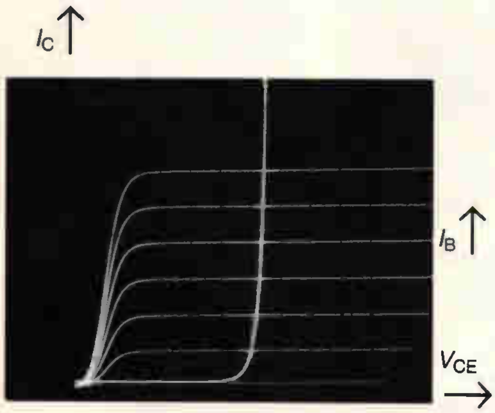


Fig. 1. Collector characteristics of a ZTX300. Scales: vertical, 0.2mA/div; horizontal, 0.1V/div.

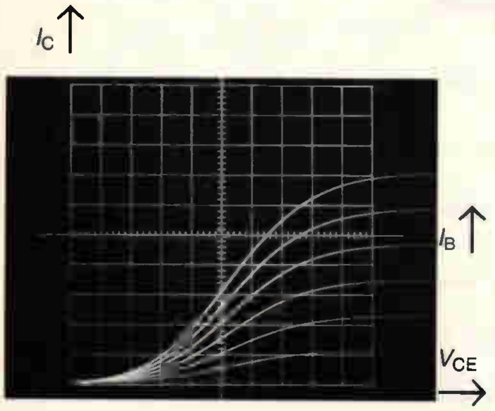


Fig. 2. Detail of Fig. 1 near the origin. Scales: vertical, 0.2mA/div; horizontal 20mV/div.

In science and engineering generally, the word 'saturation' indicates some limiting condition such as the state of magnetisation of an iron-cored transformer. With the bipolar junction transistor, or bjt, 'saturation' is commonly describes one operating state – the 'on' condition of the device used as a switch.

What, precisely though, is meant by saturation in that case? For the circuit design engineer the treatment of the topic in the literature is not, in my view, as clear and informative as it could be. For example, the saturation region has been described variously as that '...below the knee of the collector characteristics' and '...where the collector characteristics merge'.

Consider **Figs 1 & 2**, which are photographs of the collector characteristics of a general purpose low power silicon bipolar junction transistor, namely a *ZTX300*, in the vicinity of the origin. Superimposed on Fig. 1, by double exposure, is another curve dealt with later. Figure 2 shows the same characteristics as Fig. 1 but with an expanded horizontal scale.

It is apparent that there is no unique 'knee point'. Furthermore, although the curves appear to converge to a single point, they do not 'merge' in the sense of combining to form a single trace.

This article is intended to clarify the meaning of saturation. Also, in the case of common-emitter switch – i.e. 'inverter' – design, the article will justify its representation by a simplified dc equivalent circuit based on information given on manufacturers' data sheets.

To do this it is necessary first to review a general dc model of the bipolar transistor that gives a good first-order description of device performance.

The BJT dc model

A low-power silicon n-p-n transistor, symbolised in **Fig. 3a)**, is chosen for discussion because of its predominance in design work. Bear in mind that the remarks made concerning it are equally valid for a p-n-p transistor if the directions of currents and the polarities of bias voltages are reversed.

The bipolar junction transistor model of Fig. **3b)** is a 'transport' version[1] of the classic model proposed by J. J. Ebers and J. L. Moll.[2] Diodes D_E and D_C, which are assumed to have ideal exponential I-V characteristics, refer respectively to the base-emitter and base-collector junctions. As each diode may be either forward or reverse biased independently of the other, there are four possible operating modes, or regions.

These regions are indicated on the mode-map of **Fig. 4**. It is apparent that in three of them the dc model reduces to a simpler form. Thus, in the normal-active mode, used in analogue applications, D_C is reverse biased and the collector current may be regarded as dependent upon either the current in D_E or upon the potential difference across it. In the reverse-active mode the bipolar transistor works 'backwards'. This mode is not normally used.

Uses of saturation

The saturation mode, together with the cut-off mode, is used in switching circuits. In the model considered, saturation is defined *unambiguously* as that mode for which D_E and D_C both conduct.

Figure 4 applies whatever the configuration employed. **Figure 5** is an interpretation of it in the I_C, V_{CE} plane. It shows that the saturation region comprises two sub-regions. In the first quadrant, where I_C is greater than zero, it is bounded by the lines V_{CE}=0 and V_{BC}=0, i.e., V_{CE}=V_{BE}.

The near-vertical trace towards the centre of Fig.1 shows this boundary line. It was obtained by strapping together the collector and base leads of the device. The boundaries in the third quadrant, I_C<0, are set by the lines V_{CE}=0, V_{BE}=0.

In saturation, I_C and I_B in Fig. 3b) are given by the following equations, in which the sec-

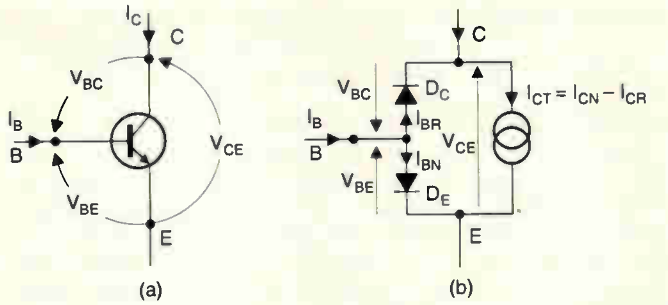


Fig. 3. Symbolic representation of an n-p-n transistor, a). On the right, b) is a dc model for a).

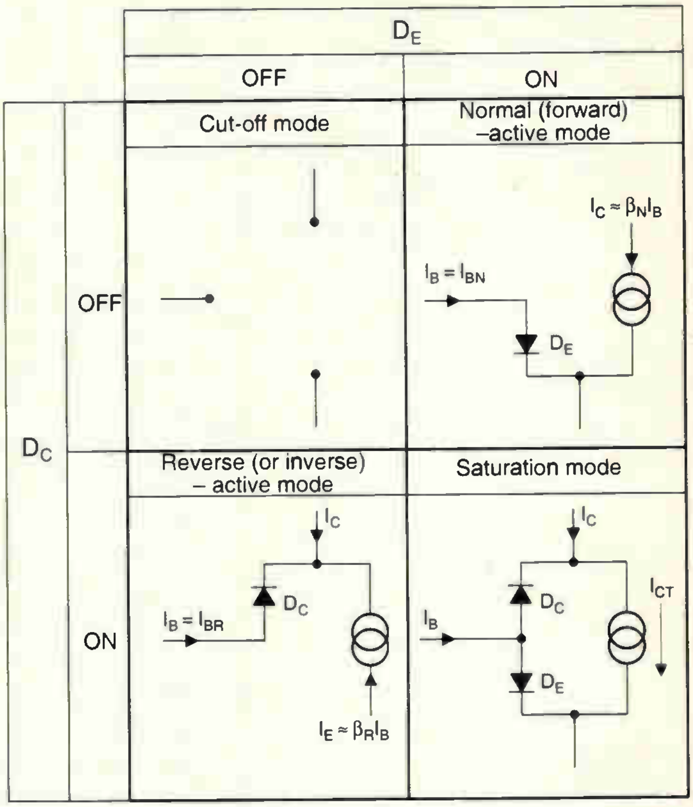


Fig. 4. Mode-map for dc operation.

ond subscripts, N and R, refer to 'normal' and 'reverse' respectively.

$$I_C = I_{CT} - I_{BR} = I_{CN} - I_{CR} - I_{BR} \quad (1)$$

and,

$$I_B = I_{BN} + I_{BR} \quad (2)$$

where,

$$I_{CN} = I_S[\{\exp(V_{BE}/V_T)\} - 1] \quad (3)$$

$$I_{CR} = I_S[\{\exp(V_{BC}/V_T)\} - 1] \quad (4)$$

$$I_{BN} = I_{CN}/\beta_N \quad (5)$$

$$I_{BR} = I_{CR}/\beta_R \quad (6)$$

In these equations, I_S is a parameter that is dependent upon device geometry – emitter area and base width – and base doping profile. It is constant at a fixed temperature.

Parameter V_T is the 'thermal voltage' kT/q, k being Boltzmann's constant, or 1.38×10^{-23}J/K, T the Absolute Temperature in kelvins (°C+273) and q is the magnitude of the electronic charge in coulombs, or 1.602×10^{-9}C.

Throughout this article, V_T is taken as 25mV, its approximate value at room temperature, 290K.

The parameter β_N is the common-emitter current gain, i.e. the ratio I_C/I_B with the bipolar transistor in the normal-active mode and $V_{BC}=0$: it is taken as being independent of I_C and T. A similar definition applies to β_R.

In the normal-active mode $I_{CR}\approx0$ and $I_C \approx I_{CN} = \beta_N I_B$.

The collector current results from all those electrons from the emitter that reach the base-collector junction and are swept across it by the field existing there. In saturation $\beta_N I_B$ exceeds the maximum current that the external circuit is able to supply. Regarding charge carrier flow within the device, there is a 'bottleneck' condition.

As the base-collector junction is not permitted a carrier flow corresponding to $I_C=\beta_N I_B$, the only way to achieve a balance is by the junction becoming forward biased. Then electrons not only arrive at the junction from the emitter but are also injected back from the collector region into the base, i.e. I_{CR} is greater than zero.

Voltage V_{BC} increases till the net flow corresponds to the current allowed by the external circuit. In that case V_{CE}, now known as $V_{CE(sat)}$, is the difference between V_{BE} and V_{BC} and is, consequently, less than either.

A bipolar transistor in saturation may be viewed as comprising two transistors, each working at the edge of saturation, i.e. $V_{BC}=0$, connected in inverse parallel.

Squirting sand

In mechanics, a crude analogy that shows the difference between the normal-active and saturation regions is provided by a nozzle squirting particles of sand at a wire mesh located a short distance from the nozzle in a plane at right angles to it.

If the mesh is extremely coarse almost all the sand particles pass through it but if the mesh is fine some particles bounce back. In this analogy, sand particles play the part of electrons, the nozzle the injecting emitter and the mesh the biased base-collector junction.

There is, incidentally, a direct link between the model of Fig. 3b) and the physical electronics of bipolar transistor operation. The link is that each of the currents defined earlier can be associated with a minority carrier charge pattern in each of the quasi-neutral regions E, B, C of the transistor.

A study of that link is rewarding for the added physical insight it offers but I will not pursue it here because this article is concerned primarily with the circuit representation of the saturated state.

In the next section, I show that Fig. 3b) can be reduced to a simpler form in the case of the inverter configuration widely used in interface circuit design. Then, in a final section, Fig. 3b) is used to demystify the operation of a standard ttl input stage and of a precision switch.

The saturated bipolar inverter

Figure 6 shows a common-emitter switch using a silicon bipolar transistor. When Q_1 is saturated its V_{CE} is not zero. As a result, Q_2 can only be cut off in the sense defined in the mode-map classification of Fig. 4. That means that D_E is off if its base is connected to the junction point of a resistive potential divider network connected between the collector of Q_1 and a negative supply rail.

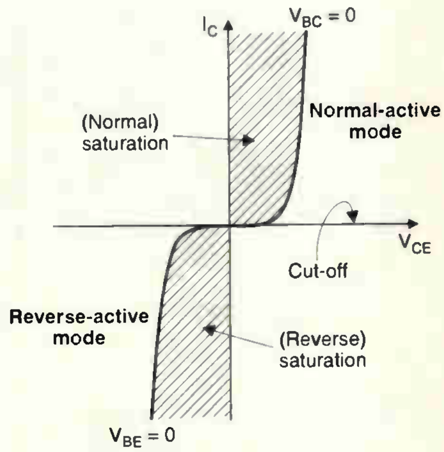


Fig. 5. Plot for I_C-V_{CE} corresponding to Fig. 4.

Since a negative rail is not used here, it is necessary to establish a relaxed practical criterion for the off condition with single rail circuits. A suitable criterion, discussed elsewhere[3] is that Q_2 may be regarded as off if its V_{BE} is less than 0.4V. This is compatible with the upper limit for a logic '0' output voltage with standard ttl.

In **Figure 7**, the load-line construction for Q_1 illustrates this requirement. Operating point P must lie not only to the left of the boundary line V_{BC}=0 but also in the region to the left of the line V_{CE}=0.4V.

Under normal conditions $V_{CC}>>V_{CE(sat)}$, so we know that $I_{C1}\approx V_{CC}/R_C$ but how to choose I_{B1} to ensure that $V_{CE(sat)}\leq 0.4$V? To answer that question you need to return to equations (1) to (6). With the usual conditions of saturation, V_{BE}, $V_{BC}>>V_T$ so you can ignore the unity terms in comparison with the exponential terms.

Now,

$$V_{CE(sat)}=(V_{BE}-V_{BC})=V_T\log_e(I_{CN}/I_{CR}) \quad (7a)$$

Expressing I_{CN}, I_{CR} as functions of I_B, I_C gives,

$$V_{CE(sat)}=V_T\log_e X \quad (7b)$$

where,

$$X=\frac{\dfrac{I_C}{I_B}+\beta_R+1}{\beta_R\left[1-\left(\dfrac{I_C}{\beta_N I_B}\right)\right]} \quad (7c)$$

In particular, for I_C=0,

$$V_{CE(sat)}=V_T\log_e\{1+(1/\beta_R)\} \quad (8)$$

'Offset' voltage

Apart from its use in the last section of this article, the $V_{CE(sat)}$ given by equation (8) deserves brief mention in another context.

Known as the 'offset' voltage, it denotes the common point of intersection of the collector characteristics. This is an important parameter of the bipolar transistor when used as a 'chopper' for microvolt level analogue signals. However, since the advent of field-effect transistors, which have no such inherent offset voltage, interest in bipolar transistor choppers has declined so that topic will not be discussed further.

From equation (7a) you can calculate I_B for a given I_C and $V_{CE(sat)}$, if β_N and β_R are known. However, β_R is not usually specified on data sheets for discrete devices. Unfortunately, it is important in determining $V_{CE(sat)}$, as shown by the curves of **Fig. 8**. The choice β_N=100 is representative of modern devices and errs on the 'safe' side: larger values of β_N merely cause the curves to move slightly nearer the horizontal axis.

Implicit in equation (7a) is the fact that $V_{CE(sat)}$ is constant with change in I_C if (I_C/I_B) is fixed. **Figures 9, 10** are pictorial interpretations of this.

The particular value of I_C/I_B necessary to guarantee a specified $V_{CE(sat)}$ is often denoted by the parameter $\beta_{(sat)}$, the 'beta in saturation'. Some writers use β_F, the subscript referring to the fact that we are 'forcing' the device to saturate. However, the subscript F is also used in describing the 'forward' active mode so there is a risk of confusion if that is used.

The parameter β_R is under the control of the device designer and largely determined by the ratio of emitter junction area to collector junction area. A 'large' ratio means a large β_R but also increased emitter capacitance, which can adversely affect switching times.

A theoretical value for the saturation voltage temperature coefficient, $TCV_{CE(sat)}$, can be found as follows. Assuming that β_N, β_R are independent of T, or have only a weak dependence on it, and that I_C/I_B is constant, $\log_e X$ in equation (7b) can be taken as temperature invariant.

Then, differentiation gives,

$$TCV_{CE(sat)}\approx V_{CE(sat)}/T \quad (9)$$

For $V_{CE(sat)}$=300mV and T=300K this gives a rule-of-thumb temperature coefficient of +1mV/°C.

In the normal active mode V_{BE} *decreases* by about 2mV/°C at fixed I_C. So how does the +1mV/°C arise? The answer is that, with fixed I_C/I_B, $V_{BE(sat)}$ and $V_{BC(sat)}$ both decrease with T but $V_{BC(sat)}$ decreases by more than the former.

The curves of Figs 1, 2 appear to validate Fig. 10. In the normal-active mode the curves for consecutive values of I_B are equally spaced in I_C. This is true also in saturation, but the spacing reduces with $V_{CE(sat)}$.

Testing the idea

A direct experimental test of the applicability of Figs 9, 10 to practical devices can be made using the circuit of **Fig. 11**, which is connected to a curve tracer. This is only a basic set-up, suitable for rapid visual checks. More refined developments of it permit accurate measurements to be made on a sweep basis or by a point-by-point plot.

Transistors Q_{P1}, Q_{P2}, connected in the grounded-base configuration, operate in the normal-active mode and supply I_B, I_C, respectively, to the bipolar transistor under test, or T.U.T.

If you assume that Q_{P1} and Q_{P2} have the same value of emitter-base drop, V_{EB}, and a common value for grounded-base current gain α_P, which is approximately unity, then,

$$I_C=\frac{\alpha_P(V_{CC}-V_{EB}-V_B)}{R_1} \quad (10)$$

and,

$$\frac{I_C}{I_B}=\frac{R_2}{R_1} \quad (11)$$

The supply rail V_{CC}, obtained from the curve tracer, is a full-wave-rectified sinusoidal waveform having a zero-volt baseline and an adjustable amplitude, so I_C=I_B=0 for V_C<(V_{EB}+V_B)≈2V and $I_C\propto V_{CC}$ for V_{CC}>>2 V.

Table 1 gives the switch settings used to obtain **Fig. 12**, which applies to the same T.U.T. as that used in Figs 1, 2.

In Fig. 12 there is a baseline corresponding to a V_{CE} of 0 and there are three traces obtained with a $V_{CC(peak)}$ of 100V so, for the top and middle traces, $I_{C(max)}$ is around 10mA and for the bottom trace, $I_{B(max)}$ is around 0.5mA.

The traces are not quite parallel to the horizontal axis for two reasons. First, β_N and β_R are not constant, as assumed. They decrease at low and high currents. However, this makes no difference to the form of the model or the applicability of equation (7b), which predicts an increase in $V_{CE(sat)}$ at low currents owing to this effect.

Secondly, the bulk or extrinsic resistances

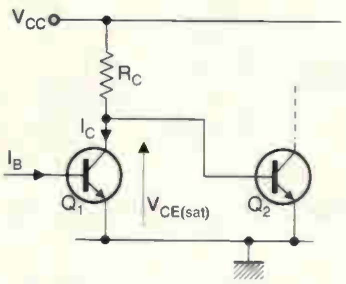


Fig. 6. Basic bipolar junction transistor inverter stage.

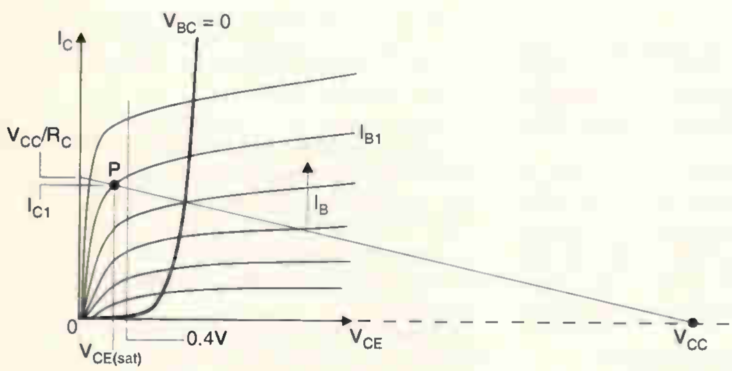


Fig. 7. Load-line construction for Fig. 6.

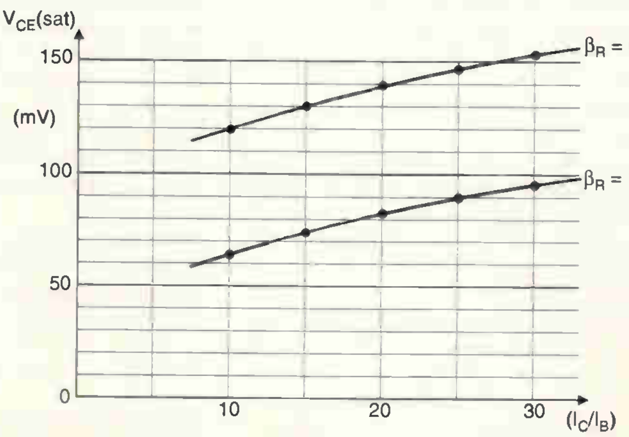


Fig. 8. Plots based on equation (7a) of the text. β_N=100.

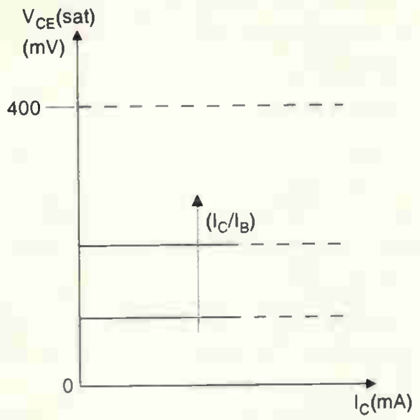


Fig. 9. Idealised saturation characteristics.

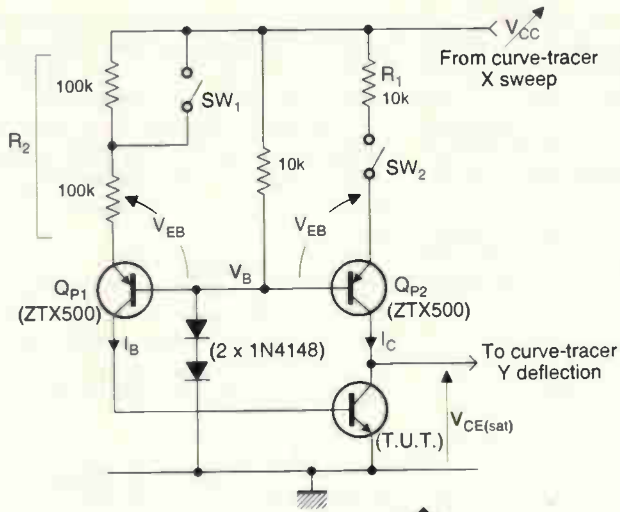


Fig. 11. Test circuit for saturation characteristics.

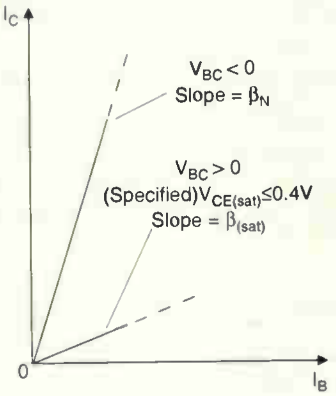


Fig. 10. Current transfer characteristics for Fig. 9.

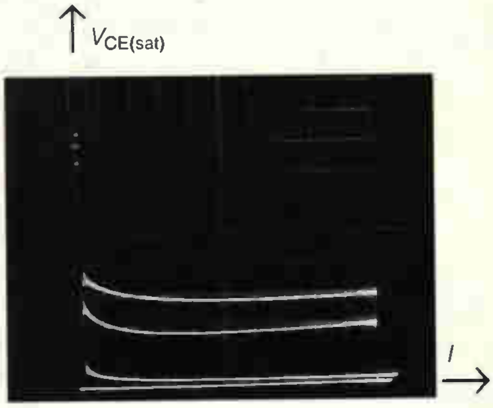


Fig. 12. Test results: $V_{CE(sat)}$ versus I for a ZTX300 transistor. Vertical scale: 20mV/div. $I_{C(max)}$, for top and middle trace, ≈10mA, $I_{B(max)}$, for bottom trace, ≈0.5mA.

Table 1. Experimental test options for Fig. 11.

Trace	Display	I_C/I_B	SW_1	SW_2	
Top	$V_{CE(sat)}$ vs I_C	20	X	●	$I_{C(max)}$ ≈ 10mA
Middle	$V_{CE(sat)}$ vs I_C	10	●	●	
Bottom	$V_{CE(sat)}$ vs I_B	0	●	X	$I_{B(max)}$ ≈ 0.5mA

● = closed X = open

r_{CX}, r_{EX}, of the collector and emitter regions, respectively, have been neglected. When these are added to the model, equation (7b) is modified to.

$$V_{CE(sat)}=V_T\log_e X+[I_C r_{CX}+(I_C+I_B)r_{EX}] \quad (12)$$

The bracketed term accounts for the positive slope on the traces. By virtue of device doping and geometry, r_{CX} is much greater than r_{EX} so the slope is mainly due to r_{CX}. This parameter depends on the process technology used in the manufacture of the bipolar transistor. The device designer has some control over it though, and it is possible to have an r_{CX} value of less than 10Ω for bipolar transistors intended for saturated switching circuits. The two parameters r_{CX} and β_R govern the choice of specified $V_{CE(sat)}$ for a given I_C/I_B.

Relating theory to practice

To see how this discussion relates to manufacturers' data sheets, consider the well established BC108.[4] The first part of saturation specification reads: $V_{CE(sat)}$<250mV and $V_{BE(sat)}$=700mV (typ) for I_C=10mA and I_B=0.5mA.

It is implicit that this $V_{CE(sat)}$ is a maximum value that includes the effect of the bracketed term in equation (12): it will be less for I_C values of less than 10mA.

The relevant saturation characteristic has the general shape and location of curve (i) in **Fig. 13**. We err on the side of safety in a 'worst-case' circuit design philosophy by assuming, instead, that the saturation characteristic is represented by curve (ii).

This is a line parallel to the horizontal axis that passes through the specification point. The ratio (I_C/I_B) associated with it is taken to be that of curve (i) and in this case is represented by the parameter $\beta_{(sat)}$ introduced earlier.

In making the curve-substitution we are imagining the BC108 to be replaced by a 'well-behaved' device that has $r_{CX}=r_{EX}=0$ and constant β_N, β_R.

Up to this point I have not considered $V_{BE(sat)}$. Equations (1) to (6) show that this increases with I_C for fixed I_C/I_B. Nevertheless, you can assume that $V_{BE(sat)}$ is constant because in a well-designed circuit it has only a second-order effect in setting I_B. Only a typical value is given for this parameter so, allowing an extra 100mV, a reasonable value for this 'constant' $V_{BE(sat)}$ is 800mV.

A simplified dc equivalent circuit for the BC108, that follows from our discussion, is shown in **Fig. 14**. As an example of its use,

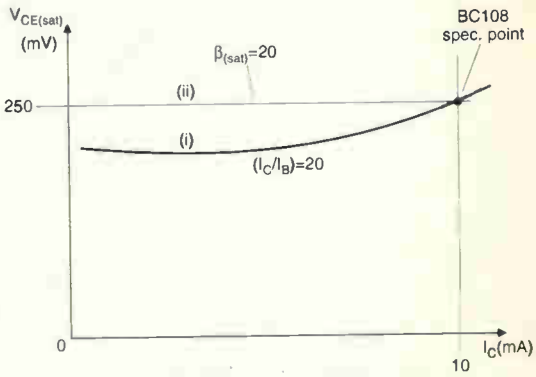


Fig. 13. Saturation characteristic for BC108: actual shape (i) and assumed characteristic, (ii).

refer back to Fig. 6 and suppose that I_B is supplied via a resistor R_B connected between the base of Q_1 and the V_{CC} rail. For the usual case $V_{CC} >> V_{BE(sat)}$, $V_{CE(sat)}$, the limit set on R_B is given by,

$$R_B \leq 20R_C \quad (13)$$

Equation (13) applies to the design of conventional collector-base coupled monostable and astable circuits using the BC108. The second part of the BC108 specification applies to a higher current range where $V_{CE(sat)}$ is less than 600mV and $V_{BE(sat)}$ is typically 900mV for a collector current of 100mA and base current of 5mA.

This is directly applicable to the design of some interface circuits, for example, those for driving a relay coil, the winding of a motor or

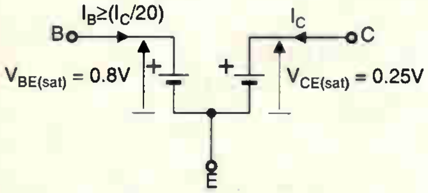


Fig. 14. Simplified saturation model for BC108, for I_C≈10mA.

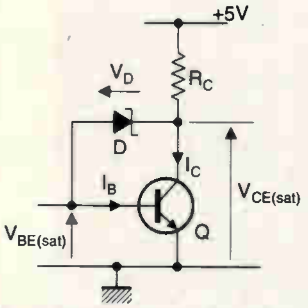


Fig. 15. Inverter stage with Schottky-diode clamping.

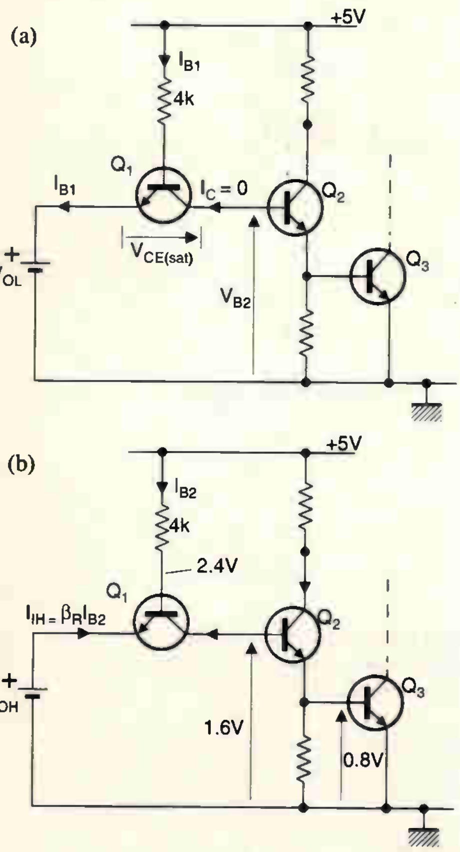


Fig. 16. Standard ttl input stage, simplified: Input level, a) '0', b) '1'.

a number of leds. However, it would be unrealistic to take $V_{CE(sat)}$ as 600mV if you wanted to operate at, say, 15mA – i.e., outside the 10mA range previously considered.

A reasonable approach then would be to estimate $r_{CX}+r_{EX}$, find the potential difference across it due to 5mA, and add that to the worst-case $V_{CE(sat)}$ at a collector current of 10mA.

Clearly, $(r_{CX}+r_{EX})\times100\text{mA}$ is less than 600mV so $r_{CX}+r_{EX}$ is less than 6Ω and the estimated value at 15mA would be 280mV.

To conclude this section, consider the well-known Schottky-diode base-collector clamping scheme of **Fig. 15**. By Inspection,

$$V_{CE(sat)}=V_{BE(sat)}-V_D \tag{14}$$

The bipolar transistor is prevented from becoming deeply saturated because V_D, at around 0.35V, is significantly less than the V_{BC} that would exist in D's absence. This results in improved dynamic performance, because of the reduction in excess minority carrier charge stored in the base of Q, but this is at the price of a higher $V_{CE(sat)}$.

The calculation of $V_{CE(sat)}$ and its spread is not simple. This is because it requires a knowledge of the *I-V* characteristic of D as well as the parameter $V_{BE(sat)}$, which is not closely specified.

Other saturating circuits

Figures 16, 17 show two circuits for which the simplified model of Fig. 14 is not appropriate because they do not use straightforward inverter stages. It is necessary to go back to the full model of Fig. 3b).

Figure **16a)** indicates the input circuit conditions existing in a standard ttl stage when the input voltage is at a logic zero level. Figure **16b)** illustrates the conditions for a logic-one level.

The input transistor, Q_1, is shown as having only one emitter. This simplifies the analysis without invalidating its general applicability.

In Fig. 16a), transistor Q_1 is saturated and Q_2, Q_3 are cut off. In this condition I_C=0 and $V_{CE(sat)}$ is given by equation (8) because the extrinsic voltage drop $I_{B1}r_{EX}$ is negligible, at around a millivolt, in comparison with the logarithmic term.

To hold Q_2 off V_{B2} needs to be less than 0.6V. As a result, a design constraint is,

$$V_T\log_e\{1+(1/\beta_R)\}+V_{OL}<0.6\text{V} \tag{15}$$

In Fig. 16(b), Q_2 and Q_3 are saturated and Q_1 operates in the reverse-active mode if V_{OH} exceeds the base voltage of Q_1. Taking a conducting junction drop as 0.8V this means that V_{OH} is more than 2.4 V.

The logic one level input current, I_{IH}, is then given by,

$$I_{IH}=\beta_R I_{B2} \tag{16}$$

To reduce gate input loading for a logic one input, choosing an I_H value of less than 40μA when, as here, I_{B2} is 0.65mA implies that β_R is around 0.06.

This satisfies equation (15) and is achievable in practice if the emitter area of Q_1 is suitably scaled down with respect to that of the collector.

From what I have said previously, it might seem impossible to meet the condition $V_{CE(sat)}$=0 with a bipolar switch. That is true for an ordinary inverter stage. However, by putting X=1 in equation (7), you find that it *is* possible to have a $V_{CE(sat)}$ of 0 if you operate with a collector current less than 0, i.e., in the reverse-saturation mode.

Figure 17a) outlines a precision voltage switch that exploits this possibility. With no base current, Q is off and $V_O=-V_{XX}$. For finite base current, it follows from equation (7a) that $V_{CE(sat)}$=0 and V_O=0 if $I_{CN}=I_{CR}$.

Then,

$$I_B=I_{BN}+I_{BR} \tag{17}$$

or,

$$I_B=I_{CR}\{(1/\beta_N)+(1/\beta_R)\} \tag{18}$$

But,

$$I_{CR}/\beta_R=V_{XX}/R \tag{19}$$

Hence, the requirement on I_B is,

$$I_B=\frac{V_{XX}}{R}\left(1+\frac{\beta_R}{\beta_N}\right) \tag{20}$$

Fig. **17b)** shows an equivalent circuit for V_O=0V. From a circuit viewpoint, Q behaves merely as a couple of 'catching' diodes, D_E and D_C, with balancing voltage drops. ■

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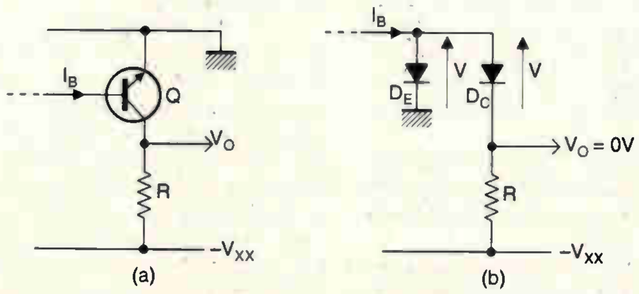

Fig. 17. A precision voltage switch: a) Circuit; b) Simplified representation for V_O=0V.

SPEAKERS' CORNER

Sound reproduction depends totally on microphones and loudspeakers containing parts that move in sympathy with the audio waveform. To build accurate loudspeakers, you need to know a little about the physics of moving masses, explains John Watkinson.

Isaac Newton explained that a mass would remain at rest or travel at constant velocity unless some net force acted upon it. If such a force acts, the result is an acceleration where $F=ma$.

Figure 1 shows a mass supported on a spring. This configuration is found widely in loudspeakers because all diaphragms need compliant support to keep them in place yet allow vibration. An ideal spring produces a restoring force which is proportional to the displacement.

The constant of proportionality is called the stiffness, which is the reciprocal of the compliance. When such a system is displaced and released, the displacement performs a sinusoidal function called simple harmonic motion or shm.

When more energy is put in to the system, it oscillates at the same frequency but the amplitude has to increase so that the restoring force can be greater.

Eventually the resonance of a mass on a spring dies away. The faster energy is taken out of the system, the greater the rate of decay. Any mechanism which removes energy from a resonant system is called damping. In a loudspeaker this could come from losses in the spider, the surround, or from electromagnetic damping in the coil. Acoustic radiation also extracts energy.

The motion of a rigid body can be completely determined by the mass, the stiffness and the damping factor. As audio signals contain a wide range of frequencies, it is important to consider what happens when resonant systems are excited by them.

Audio excitement

Figure 2 shows the displacement, velocity and acceleration of a mass, stiffness, damping system. This system is excited by a constant amplitude sinusoidal force acting on the mass at various frequencies.

Below resonance, the frequency of excitation is low and little force is needed to accelerate the mass. The force needed to deflect the spring is greater and so the system is said to be stiffness controlled. The amplitude is independent of frequency, described as constant amplitude operation, and so the velocity rises at 6dB/octave towards resonance.

Above resonance, the inertia of the mass is greater than the stiffness of the spring and the system is said to be mass controlled. With a constant force there is constant acceleration, yet as frequency rises there is less time for the acceleration to act. Thus velocity is inversely proportional to frequency which in engineering terminology is –6dB/octave.

The radiating ability of the diaphragm is proportional to velocity, i.e. it rises at 6dB/octave. The frequency response in this region is flat because the two slopes cancel. Mass control is commonly found in loudspeakers for this reason.

It will be clear that the behaviour just noted has a direct parallel in the behaviour of an electronic damped tuned circuit consisting of an inductor, a capacitor and a resistor and the mathematics of both are one and the same. By converting mechanical parameters into electrical parameters the behaviour of a mechanism can be analysed as if it were an electronic circuit. This is particularly common way of modelling loudspeakers.

Cone acceleration

In mass controlled loudspeakers we are interested in the cone acceleration. You will see from Fig. 2 that far above resonance the acceleration is in phase with the input signal, which is the desired result. However, as frequency falls the phase response deteriorates to 90° at resonance and a phase reversal below. The rate of

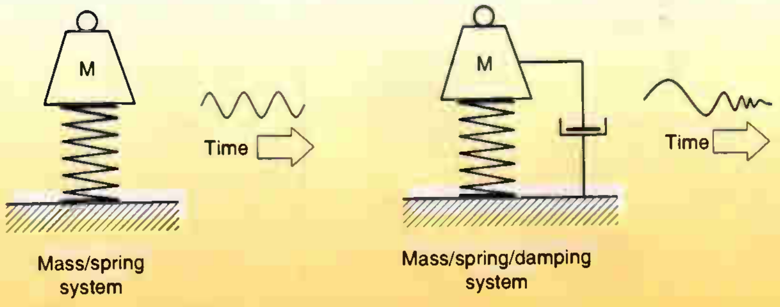

Fig. 1. Illustrates the effects of damping on a spring/mass system.

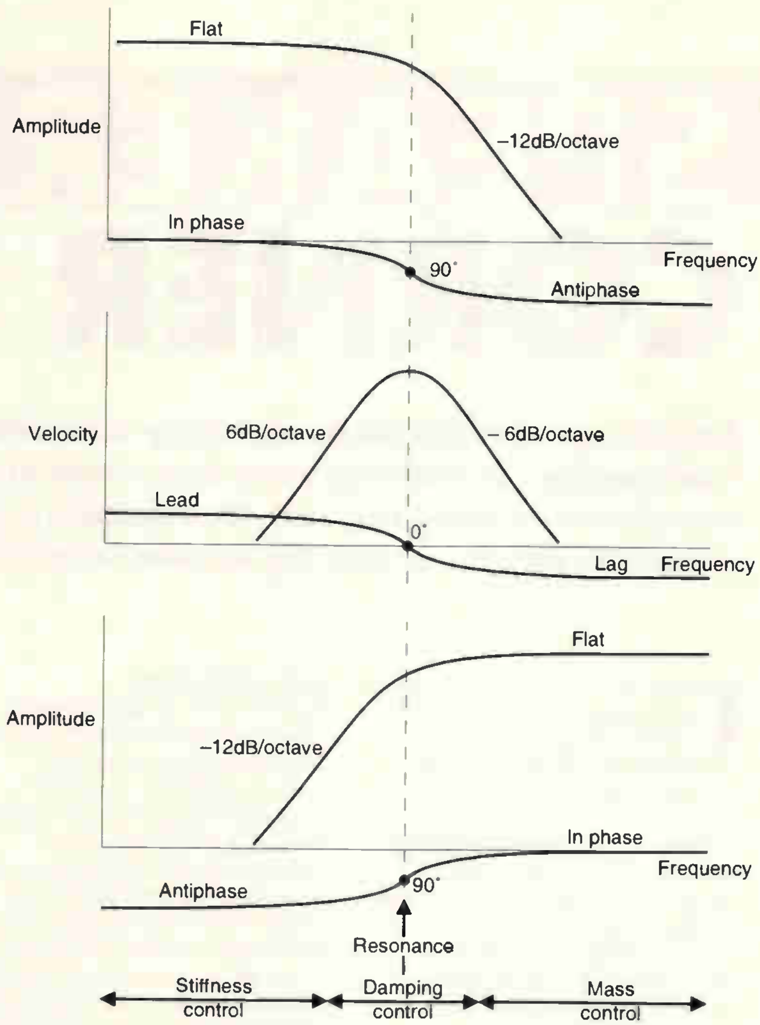

Fig. 2. Displacement, velocity and acceleration curves of a mass-stiffness-damping system assuming sinusoidal excitation force acting on the mass.

phase change in the vicinity of resonance is a function of the damping.

The phase reversal around the fundamental resonance means that a simple loudspeaker cannot reproduce the input waveform at low frequencies. Even if the resonance is set below the useful audio band, it will be clear from Fig. 2 that the effects of the varying phase response are present well into the band. These effects are audible as a footprint which gives a loudspeaker a characteristic "sound" which it should not have.

One direct consequence of the phase lag is that the acoustic centre of the loudspeaker moves backwards as resonance is traversed. The sound source appears at a distance which is a function of frequency. To the best of my knowledge genuine sound sources don't have this attribute so the loudspeaker must be creating an artifact.

Changes to the damping factor around resonance can be heard. A lightly damped system produces plenty of low frequencies but suffers hangover. A well damped system lacks lf but reproduces transients well. Clearly both are wrong, we are just changing the nature of the artifact rather than eliminating it.

Every loudspeaker designer has seen the electrical equivalent circuit which models the behaviour of a loudspeaker. But few make the connection that an unwanted mechanical resonance or phase change can be suppressed by incorporating at some point a suitable electronic circuit designed to have the opposite characteristic. Units like this don't just sound better, they sound more like the original which is the only useful criterion.

Yet again the same conclusion is reached: only active speakers can go beyond fundamental quality restrictions of passive technology. Until loudspeaker design ceases to be a subset of carpentry there is little prospect of widespread change. ■

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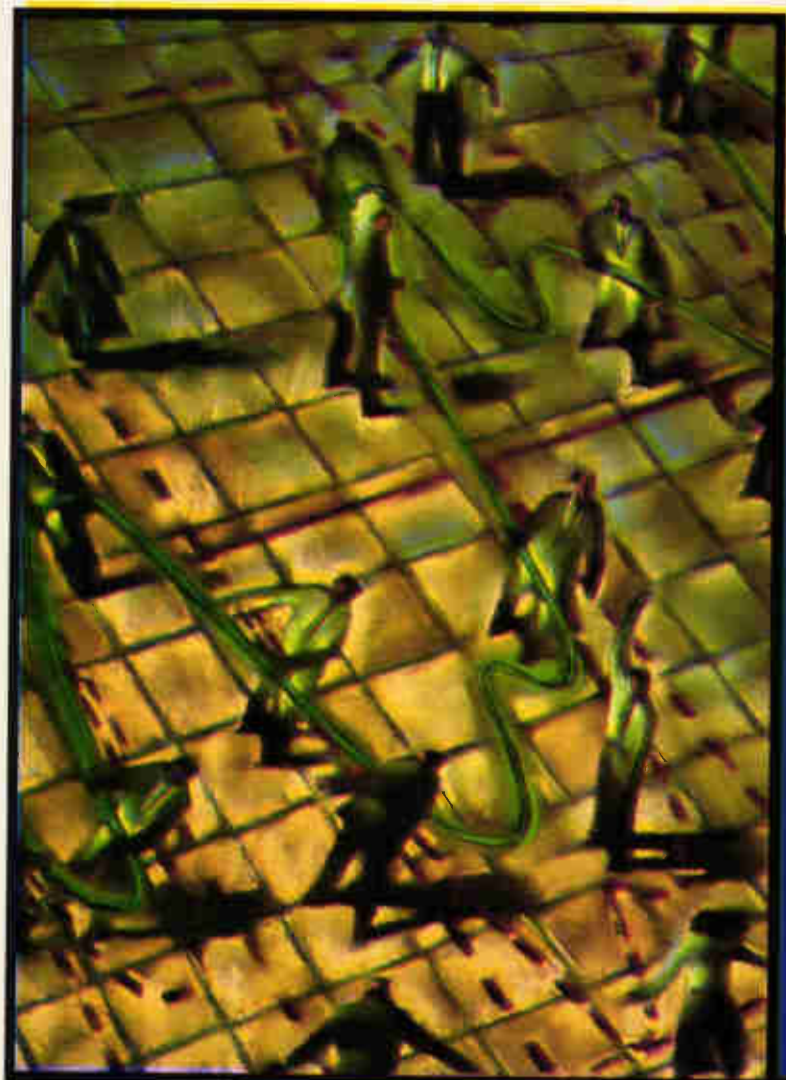


Although usually a nuisance, non-linearity can be a useful design tool. Various non-linear shaping techniques, giving a 'bendy' transfer characteristic, have been invented. Ian Hickman looks at a selection of ideas, and suggests uses for them.

Shaping up

Linearity is a highly prized quality in most electronic circuits. More often than not, the output of an amplifier for example needs to be a highly faithful replica of the input. This is especially so in audio amplifiers.

Another example of the need for linearity is waveform generators. Unlike amplifiers, generators have no input, but some types are asked to produce a very linear output.

Just how this has been achieved over the years is described in reference 1.

Intentional non-linearity

But in some applications, a non-linear amplifier or waveform generator may be required. Often, the intention is to cancel the non-linearity of the output of a sensor, or the transfer function of some other device, by subjecting it to a non-linearity of the opposite sense. Thus a 'bendy' law can be linearised by an amplifier with a transfer curve that bends the other way.

Obtaining a characteristic which is non-linear but smooth is not easy. There should of course be no discontinuities in the curve, but also there should be no discontinuities in its gradient – first differential or slope.

Ideally also there should be no discontinuities in the curve's second differential or radius of curvature, perhaps even no discontinuities in the rate of change of radius of curvature, i.e. the third differential.

But for some applications, all of this can go by the board, and a piecewise linear approximation be near enough.

Figure 1 outlines a clumsy – but effective – approximate square-law circuit I applied in a psophometer – a true-rms reading audio noise-measuring telephone voltmeter. This was used in an instrument designed for a Post Office contract back in the sixties, long before the appearance of rms-to-dc converter ICs such as the *AD536*.

The square-law circuit was followed by an IC 'ideal rectifier' stage and the resultant dc smoothed by the inertia of the moving coil indicating instrument. The square root function was looked after by a suitable non-linear scale on the meter.

In Fig. 1, the diodes and associated resistors of various values implement a piecewise approximation to a square-law current versus voltage characteristic in the first and third quadrants. The fairly soft takeover, as each diode clamped further voltage drop across its parallel resistor, resulted in a smoothish curve.

Of course the diode forward voltage drops – which set the 'breakpoints' of the piecewise approximation – will vary by about 0.4%/°C. Consequently, there must have been some temperature compensation included somewhere, and fortunately the required operating temperature range was really rather mild.

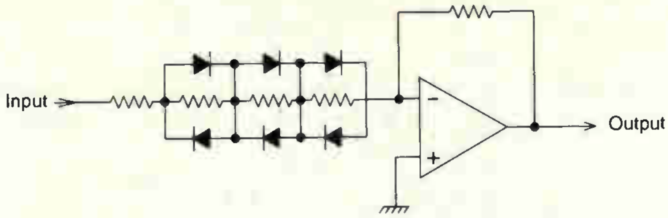


Fig. 1. A circuit giving an output voltage, on each half cycle of the input, of the same polarity as the input but of magnitude equal to the input squared. Used in the sixties as part of the rms response of a psophometer.

Fixing the breakpoints

A more sophisticated piecewise linear approximation has been described, where the diodes defining the breakpoints are included within the feedback loops of op-amps. This renders the breakpoints completely independent of temperature.[2] The arrangement is shown in **Fig. 2**.

At each of the breakpoints, a defined change of slope of the transfer characteristics is obtained. By setting the position of the breakpoints, and the change of slope at each, a given curve can be closely matched. Clearly, the more breakpoints, the closer the match that is possible.

The breakpoints V occur at the following voltages, and beyond each breakpoint the slope S takes the value indicated:

$V_1=15(R_4/R_5)$ $S_1=R_o/R_1$
$V_n=15(R_4/R_n)$ $S_n=R_o/R_1+R_o/R_2+...+R_o/R_n$

while the slope is zero up to V1.

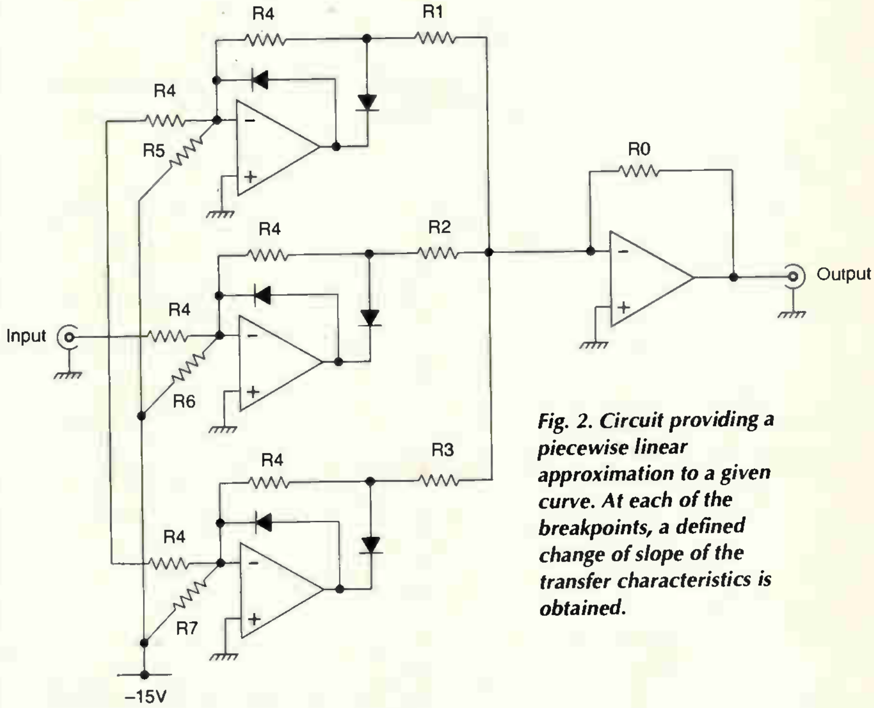


Fig. 2. Circuit providing a piecewise linear approximation to a given curve. At each of the breakpoints, a defined change of slope of the transfer characteristics is obtained.

Getting rid of the corners

I recently wanted a circuit which provided a smoothly curved response, without discrete breakpoints inherent in a circuit such as Fig. 2. After some experimentation, such an arrangement was arrived at, incidentally not involving lots of op-amps and diodes.

It seemed that as a diode provides a non-linear relation between forward voltage and current, it should be possible to use this to provide a circuit with a non-linear response. Both diodes and – more particularly – transistors have frequently been used to provide a logarithmic response, but that was not what was wanted in this case.

The first version dreamed up is shown in **Fig. 3**. The voltage $-V$ is in the few hundreds of millivolts range, and is strategically chosen so that the diode is just conducting slightly. If the voltage fed to the non-inverting input is zero, i.e. R_1=0Ω, then the inverting input is a virtual earth.

The diode therefore has no effect, other than demanding a positive offset at the output. This supplies the current that the diode sinks, and the circuit works as a normal inverting amplifier, apart from the offset. **Figure 4**, upper trace, shows the output when the input is a triangular wave – a nice linear response.

If R_1 is finite, feeding a small portion of the input waveform to the non-inverting input, the inverting input is no longer a virtual earth. The feedback will do what ever is necessary to force the voltage at the inverting input to follow that at the non-inverting input. In this way, the same small portion of the input waveform appears also across the diode.

The current the diode sinks is therefore now a function of the input waveform, and what was previously a constant offset at the output is now variable.

With a positive-going input, the diode will sink more current, so less current is sunk by the feedback resistor R_4, resulting in a smaller negative going output. Conversely, with a negative going input, the diode sinks less current and a larger positive going output voltage – and current through R_4 – is necessary to balance the current through R_3.

The result is a distorted triangle wave, the slope of which

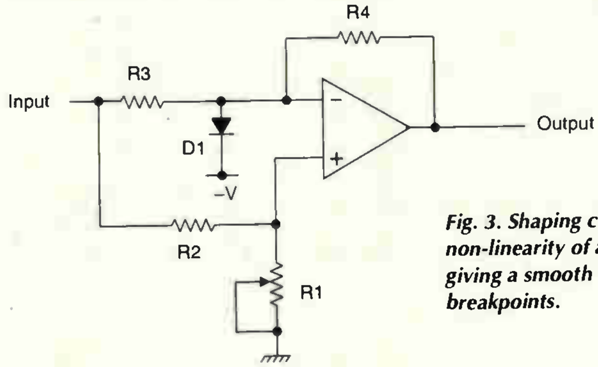


Fig. 3. Shaping circuit using the non-linearity of a single diode, giving a smooth response free of breakpoints.

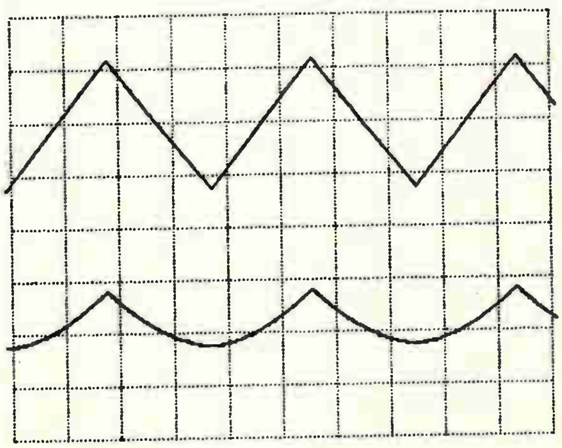


Fig. 4a) upper trace; with R_1 in Fig. 3 shorted, the output with a triangular wave input is undistorted as shown.
b) lower trace; with the two potentiometers in Fig. 5 suitably adjusted, the peaks of the waveform are exaggerated, and the troughs compressed.

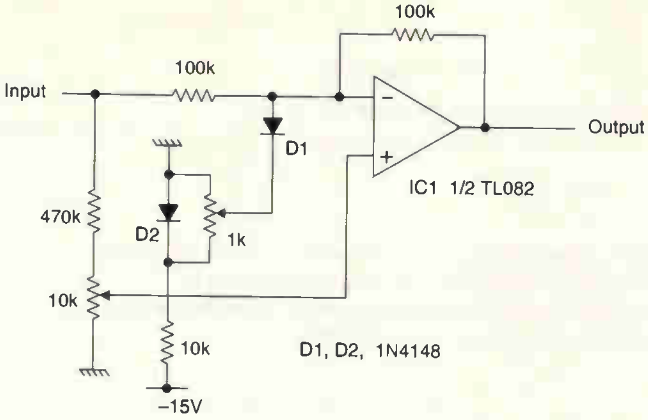


Fig. 5. Circuit with temperature compensating diode added, and showing component values.

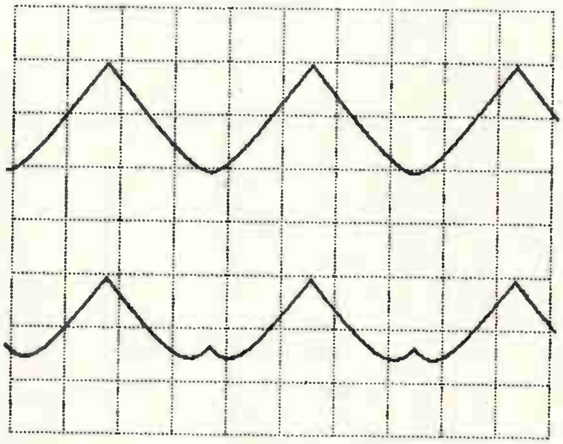


Fig. 6a) upper trace; if the signal applied to the non-inverting input is larger, and the diode forward bias lower, only the negative going peaks of the output are affected.
b) lower trace; if the diode bias is now increased, the negative peaks are not merely compressed, but actually inverted.

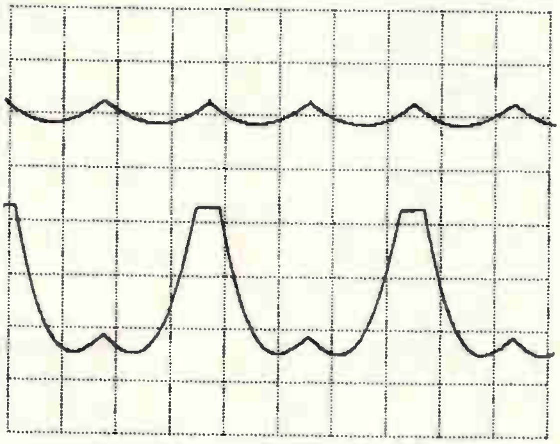
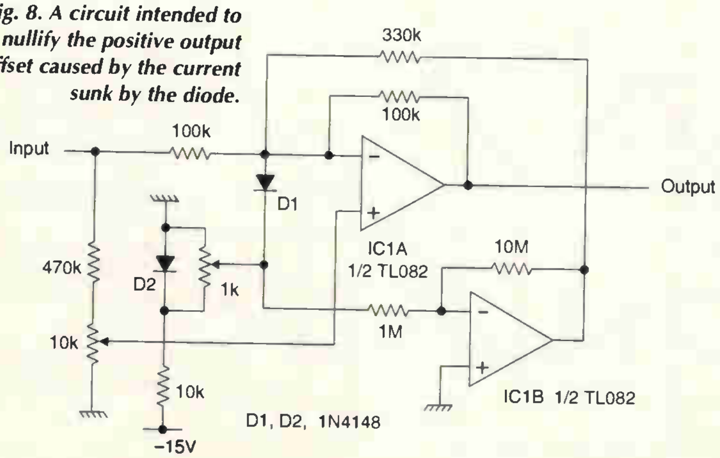


Fig. 7a) upper trace; if the diode forward bias is increased sufficiently, the circuit becomes a perfect frequency doubler.
b) lower trace; if the amplitude at the non-inverting input is now increased, what were previously the negative peaks are now more positive than the erstwhile positive peaks themselves.

Fig. 8. A circuit intended to nullify the positive output offset caused by the current sunk by the diode.



nevertheless varies smoothly everywhere, as shown in Fig. 4, lower trace. The positive-going peaks are exaggerated, and the negative-going peaks compressed. The degree of this intentional distortion is adjustable, by means of the voltage applied to the cathode of the diode and the amplitude of the fraction of the input signal applied to the non-inverting input.

How does temperature affect it?

The forward voltage drop of the diode will of course vary slightly with temperature. This was undesirable for the application I had in mind for the circuit.

So some compensation was provided, to stabilise the response shown in Fig. 4 against ambient variations. This was achieved with the use of another diode, as shown in the practical circuit of **Fig. 5**. The two diodes were mounted side by side, touching, and a temperature test run.

When the ambient temperature was raised from 20°C to 30°C, there was a 1V shift in the dc level of the output, but its 5V peak to peak amplitude and degree of shaping showed very little change.

While the compensation would be nowhere near adequate for instrumentation on an arctic expedition, for the intended application in a laboratory environment it was adequate, as the application required that the waveform was ac coupled.

An intriguing circuit

Before going on to apply the circuit, its performance was investigated further. It turns out to have interesting properties, with other possible uses, when set up differently.

The voltage applied to the cathode of the diode, and the fraction of the input applied to the non-inverting input interact to provide a number of different modes of operation.

If the voltage at the cathode is rather low, and the amplitude applied to the non-inverting input larger than used when recording the performance shown in Fig. 4, the diode will cut off completely on negative going excursions at the input. So positive peaks at the output will be unaffected, with just some compression of the negative peaks, as shown in **Fig. 6a)**.

If now the diode forward bias be increased, the negative peaks are not merely compressed, but actually inverted, Fig. **6b)**. The reason is that as the current through the diode increases, its slope resistance becomes lower and lower. Thus the inverting input is almost shorted to ground, and the circuit tends toward non-inverting operation.

If the process is carried further, the inverted negative peaks of Fig. 6b) rise up until they reach the same level as the positive peaks. At this point, the circuit becomes an ideal squarer, as shown in **Fig. 7a)**. Later, this is shown even more dramatically in the upper trace of Fig. 10. There, a 440Hz sinewave – i.e. concert pitch A above middle C, is doubled to a very respectable 880Hz sinewave an octave higher, lower trace.

Push the circuit a little further, as in Fig. **7b)**, and the diode clamps the inverting input hard on the positive peaks of the input. The circuit now becomes non-inverting, with large positive output peaks coinciding with the positive peaks of the input. These peaks hit the positive supply rail in the example shown.

In Figs 4, 6 and 7, the oscilloscope was externally triggered from the input triangle-wave generator. So you can see by comparing Figs 6 and 7, that the large peaks in Fig. 7b) correspond with the inverted negative peaks in Fig. 6b).

Compensating the offset...

The two potentiometers in Fig. 5 jointly set the degree of shaping achieved. But as I mentioned earlier, adjusting the diode bias has an additional effect: it introduces a positive offset into the output voltage, of magnitude varying with its setting.

This offset is clearly inconvenient, although once the

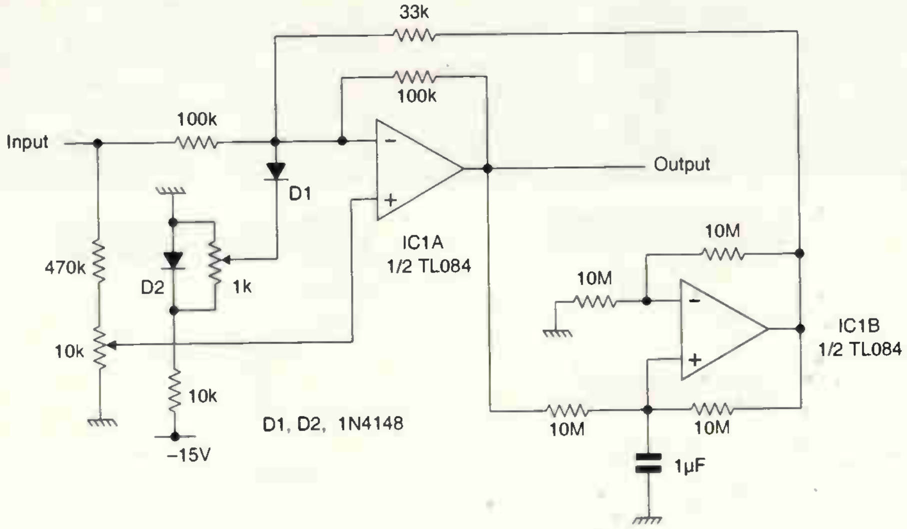


Fig. 9. A more effective offset cancellation scheme using a de Boo non-inverting integrator.

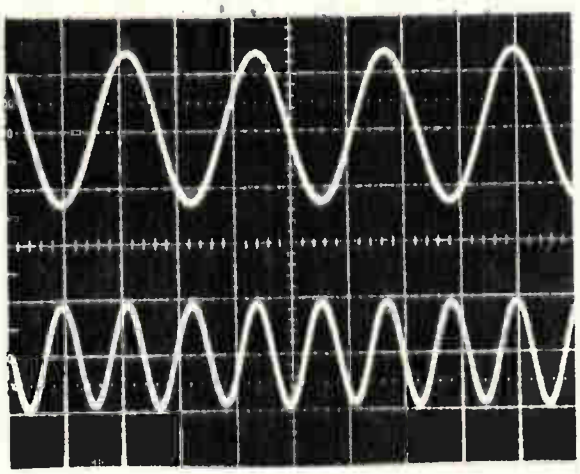


Fig. 10. A 440Hz sinewave input, upper trace (5V/div., 1ms/div.), applied to the circuit of Fig. 9, is doubled to give a an 880Hz sinewave output, lower trace (1V/div., 1ms/div.).

desired degree of shaping has been achieved, it can be removed. The simplest way of doing this is to connect a resistor of suitable value from the anode of the diode to the positive supply rail. This resistor now provides the standing current sunk by the diode, so that when the input signal is at zero volts, so is the output.

While effective, this compensation can only be achieved once the potentiometer settings are determined. It would be convenient if adjustments did not change the offset, better still if it did not introduce an offset at all.

Figure 8 shows a modification that goes some way towards this. Another op-amp picks off the negative voltage at the cathode of the diode, and applies a positive voltage to a resistor, forcing a current into the inverting junction.

If this current equals that sunk by the diode, there is no output offset, but in practice, some variation of offset with potentiometer settings remains.

...with a de Boo integrator

While the compensation provided by the additional circuitry in Fig. 8 is only approximate, it proved useful in setting up.

An improved arrangement is shown in **Fig. 9**. This uses a non-inverting 'de Boo' integrator to monitor the long term average voltage at the output of IC_1. This is compared with a zero volts reference – ground – by virtue of the resistor to ground at the inverting input of the integrator IC_2.

If the average IC_1 output voltage tries to go positive, the integrator injects a compensating current of exactly the right amount at the inverting input of IC_1. This provides the standing current sunk by the diode, leaving the mean voltage of the output waveform ground-centred.

The time constant of the integrator is more than adequate to ensure that it has no effect on IC_1's output waveshape. When either potentiometer is adjusted, a temporary offset is caused, but the output voltage trace slides gently back into the ground-centred position over a period of a few seconds.

The arrangement completely negates the offset shift with temperature described earlier.

Could be useful...

Interesting though this circuit is to experiment with, it was nevertheless developed with a particular serious application in mind – an application where a discrete breakpoint approach definitely shows its limitations. This is the linearisation of a voltage controlled oscillator tuned by means of a varactor.

At first, the reverse capacitance of a varactor diode decreases rapidly with increasing reverse voltage. This decrease slows down though as the voltage increases further.

Various laws have been proposed to describe the capacitance/reverse-voltage law, but the exact nature for any given varactor depends on the particular doping profile of the semiconductor junction region.

Whatever the law, a linear sawtooth frequency sweep requires distortion of a linear sawtooth tuning voltage waveform. The peak of the waveform, which more negatively biases the diode, needs stretching out to make it more peaky. At the same time, the other half of the sawtooth, where the reverse bias is at its minimum, needs compressing or gently squashing.

This is a function which the circuit described above accomplishes elegantly, without any slope discontinuities or breakpoints. I intend to try incorporating it in a special purpose frequency sweep circuit circuit in the near future.

The two potentiometers provide a continuous range of nonlinear laws, and with luck, one pair of potentiometer settings should just do the job. ■

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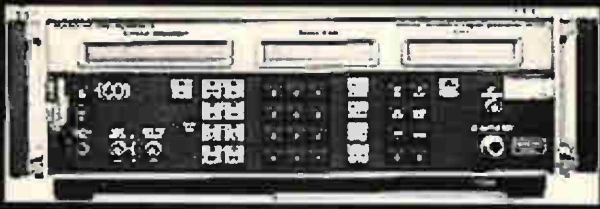

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Hands-on Internet

Cyril's found new humidity sensing information on the Net, together with details on recovering signals swamped in noise. But first, an update on operating systems, bugs and year 2000 problems.

Following the collapse of the eleventh hour discussions between the DoJ and Microsoft, Windows 98 was shipped to oems on Monday 18 May and released for general sale on 25 June.

The DoJ and some twenty states have now taken further legal action and the Microsoft trial date has been set for 8 September. Reported in *pcweek*[1] number two at Microsoft Steve Ballmer has been officially appointed its President. Bill Gates remains Chairman/CEO and now plans to devote much of his time to product development.

Clnet has published an interim test review[2] of the shrink-wrap version of Windows 98, with recommendations and performance expectations, aimed at six typical user levels. Using hardware ranging from 486DX/66 to a Pentium II clocked at 400MHz, they find Windows 98 from 6% to 23% slower than Windows 95 without Explorer, but 9% faster than Windows 95 with it.

While NT4 offers a relatively restricted choice of hardware drivers, NT5 will offer a wide choice, similar to Windows 98. The second beta of NT5 is now due and product release is due next year. Since many electronic design software developers are already promoting NT as their preferred long term engineering software platform, which system should one now choose?

If, like me, you are still running OS/2, Win3.1 or Windows for Workgroups, and have older hardware, then upgrading to Windows 98 seems the logical choice. If you are already running the latest version of Windows 95 with the OSR2.1 upgrade, your operating system choice is less clear-cut.

Windows 98 offers two significant benefits. If you have run out of interrupts, then its support for the USB port is particularly attractive.* This port allows 'hot' plugging of external peripherals. W98's 'Fat32' file system improves hard disc utilisation. Interested readers will find more background information to aid their choice by referring to the ClNet[3] and Chicago Tribune[4] articles.

Bugs...

A major trojan horse bug has been revealed in three of the most popular e-mail programs. Researchers at a Finnish University discovered the bug while performing security testing on Windows NT. Eudora apparently is not affected, but Microsoft has already posted patches for its Outlook 98 and Outlook Express programs. Netscape Mail version 4.x and above for Windows was also vulnerable and a patch for this will be provided.[5] It seems earlier versions are not affected, **Fig. 1**.

Discovered while testing Windows NT, this bug is a software fault. As a result, Windows 95 and Windows 98 operating systems running these same e-mail applications are also affected.

The bug affects the way e-mail clients handle file attachments with extremely long file names. The e-mail 'tags' containing the names of attached files put no limit on the length of file names which can be used. This means that they could contain the entire code for a hidden rogue application.[6]

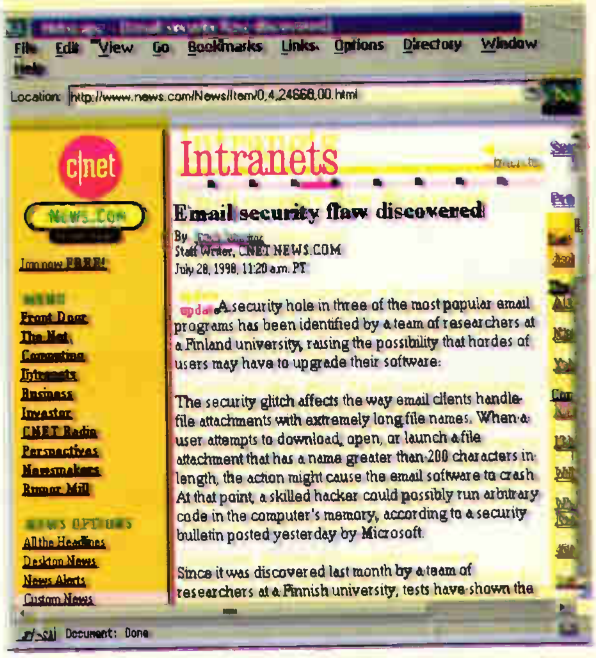

Fig. 1. If you use Outlook98, Outlook Express or Netscape Mail v 4 and receive E-mails with attached files, your computer could be at risk.

Server and workstation versions of

*The latest oem version of Windows 95 has universal serial bus support too. I believe this to be the fourth release of 95 – Ed.

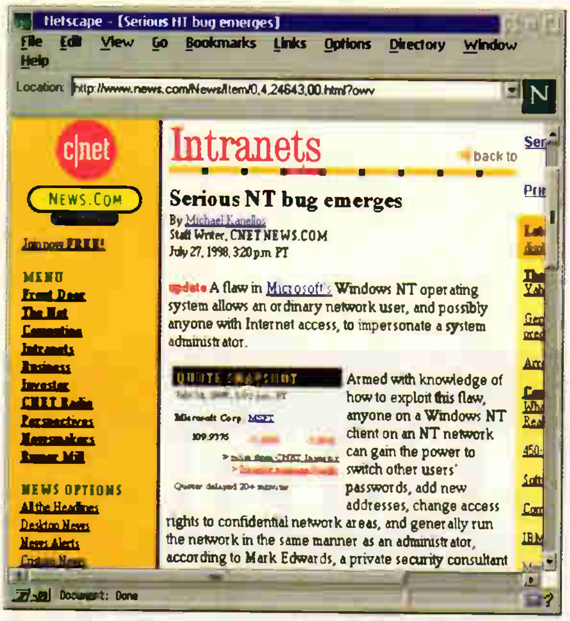

Fig. 2. Potentially serious – even for a stand-alone NT system with Internet access and all NT networked systems.

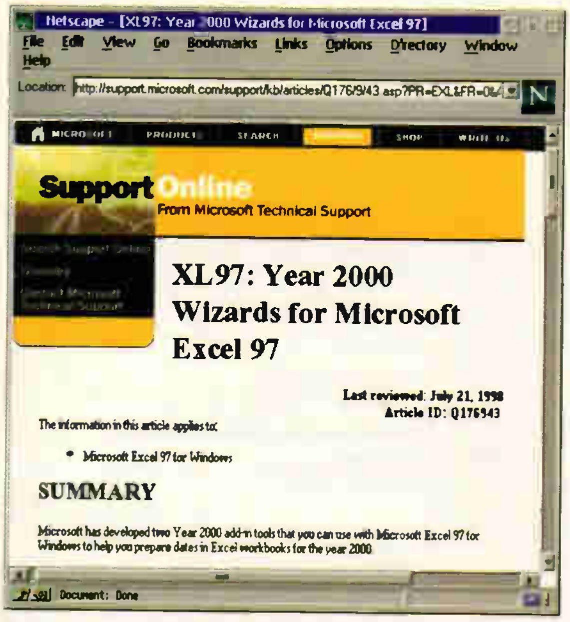

Fig. 3. Incorrect handling of dates – especially when using two digits for the year – can have undesired effects in the next century.

Windows NT 4.0 and 3.51 operating systems have a security flaw which allows an ordinary network user, and possibly via internet access, to impersonate a system administrator. Reported by News.Com,[7] Mark Edwards of the NTSecurity Web page said "its probably one of the top five or six bugs for Windows NT".

Suitable program code, if executed through a seat on an NT network, seeks out the highest system-level authority it can find for its user. This program gets the network to grant the user 'debug-level' rights. That user is then able to impersonate the system administrator, **Fig. 2**.

2000 problems, or more

According to Microsoft, Windows 98 is year 2000 compliant for two digit years, provided two files have been updated. The first file, Date Time Picker, or comctl32.dll, is common to all systems. Download and install file '401comupd.exe' from msdownload.[8]

The second update varies according to which internet Web browser you use. Microsoft Wallet which is involved with internet credit card transactions, needs updating to parse two digit year entries correctly.[9]

A recent update to the Microsoft Knowledge Base, article Q176943 for Excel 97,[10] offers two add-in tools or wizards for year 2000 compatibility. You can use within Excel 97 to help you prepare any dates used, **Fig. 3**.

The Year 2000 Download Site,[11] conveniently offers direct links to download patches for all the Microsoft operating systems discussed in this and the earlier articles, together with many other useful links and articles.

New humidity notes

Temperature is easily measured electronically, but humidity has always been rather more difficult to ascertain. Over the years various methods based on the temperature difference between wet and dry thermometers, or change in length of pieces of catgut have been traditionally used.

A recent application note from Philips Passive Components,[12] available from their Web site as 'moisture.pdf', describes two simple circuits which enable electronic control or measurement of humidity.

The sensor used is a specially constructed polymer film capacitor using very thin, air-permeable gold electrodes. Change of humidity causes the capacitor's dielectric constant to change almost linearly from its nominal 122pF at 43% humidity to some 140pF at 85% humidity, at room temperature.

Usable from 10% to 90% humidity and from –25 to 85°C, its 0.4 ±0.5pF capacitance change/%relative humidity, permits accurate humidity measurement using simple circuits. Two Philips examples are shown. The simpler bistable IC-based circuit **Fig. 4** can be battery powered while the larger circuit incorporates a linearising network for improved accuracy, **Fig. 5**.

Both circuits need calibrating for humidity, a task easily performed by suspending the sensor inside an airtight container holding a saturated solution of a known salt at 25°C. The Philips application note includes a list of suitable salts, permitting calibration over the range 11.3% to more than 90% relative humidity, together with full instructions.

Back from the noise

Extracting a very small low level signal submerged in very much larger amplitude noise is a difficult task. Analog Devices[13] illustrates a 'lock-in' amplifier acting as a synchronous detector and narrow band filter.

The company's *AD630* balanced modulator/demodulator integrated

Where to surf

1. Ballmer named Microsoft president. http://www.zdnet.com/pcweek/news/0720/2/mball.html
2. Windows 98. http://www.cnet.com/Content/Features/Special/Win98
3. USB: is your pc connected. http://www.cnet.com/Content/Reports/Trends/USB/ss02.html
4. Living off the FAT32 of the land. http://cgi.chicago.tribune.com.tech/columns/0,1710,1,00.html
5. E-mail security flaw discovered. http://www.news.com/News/Item/0,4,24668,00.html
6. E-mail Hole Exposes Computers. http://www.wired.com/news/news/technology/story/14034.html
7. Serious NT bug emerges. http://www.news.com/News/Item/0,4,24643,00.html
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9. Windows 98. http://www.microsoft.com/ithome/topics/year2k/product/win98.htm
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13. Analog Devices Inc. - AD630. http://www.analog.com/pdf/ad630.pdf
14. Spectrum-Software. http://www.spectrum-soft.com

circuit is used to recover a 400Hz carrier modulated by a 0.1Hz sine wave, which was swamped by a 100dB larger amplitude, band limited and clipped white noise source. This combination of signals was chosen to simulate the wanted signal from a chopped radiation detector, buried by background and detector noise.

The *AD630* is basically a precision op amp with two independent differential input stages, with a precision comparator able to quickly select which input channel is active. Its –100dB of crosstalk between the two input stages, facilitates synchronous recovery of these buried signals, **Fig. 6**.

The oscillogram clearly shows how this simple circuit can be extremely effective when used as a lock-in low frequency amplifier, to recover a wanted signal, **Fig.** 7.

The simple test circuits illustrated are usable at considerably higher frequencies, when additional low-pass filtering of the output would aid in rejecting wider bandwidth interference.

Simulation

In the July issue I described how many simulation and design software packages were upgrading to support only Windows 95 or Windows NT. One exception, the popular Micro-Cap simulator[14] was recently upgraded as Micro-Cap V version 2.0.

Micro-Cap V is a 32bit analogue/digital simulator with an intuitive user interface and more than 10000 pre-modelled library parts. Micro-Cap V however, still supports all Windows operating systems. For those of you wanting to evaluate this simulator, a working but free of charge, 1.75Mbyte demo version can be downloaded from the Spectrum Software Web site. ■

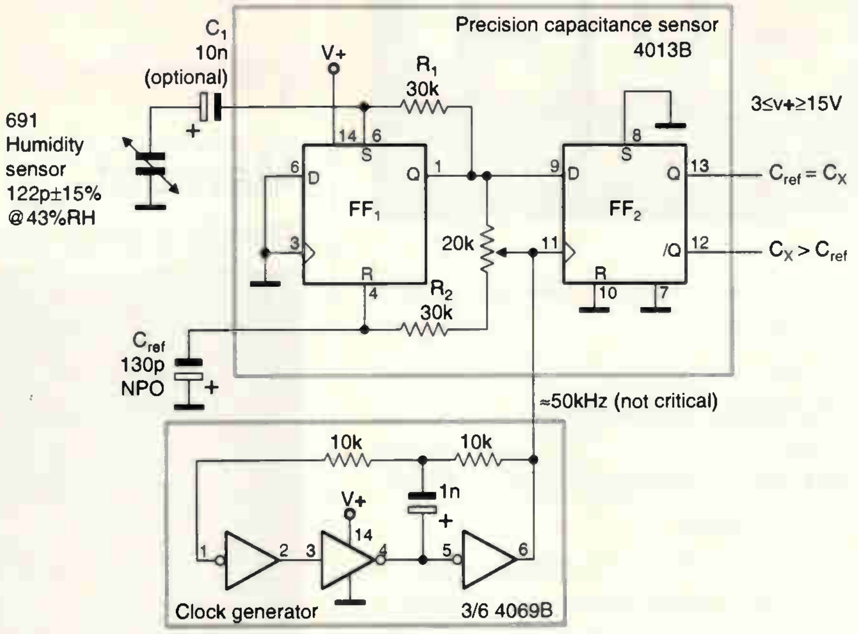


Fig. 4. The basis of a simple and portable hygrometer.

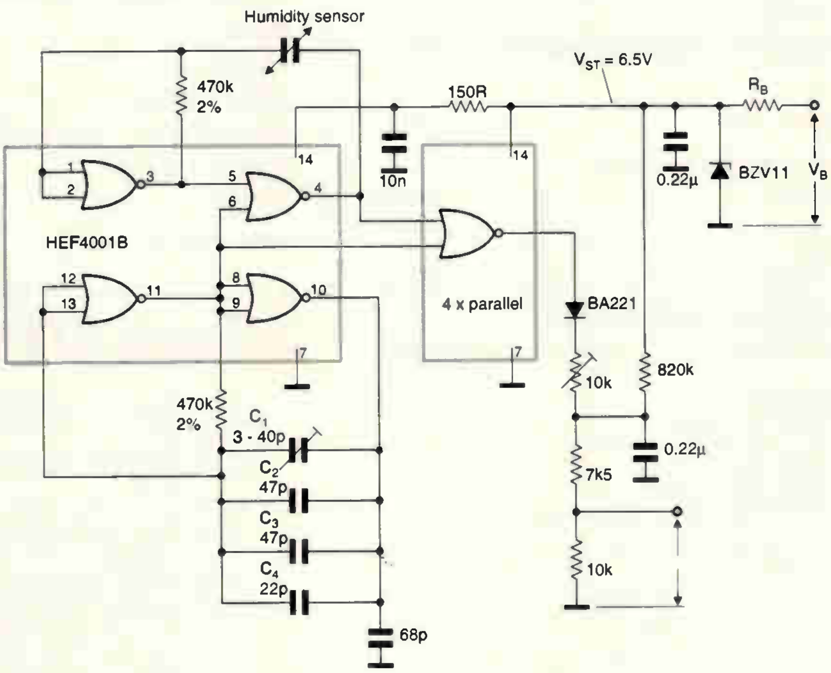
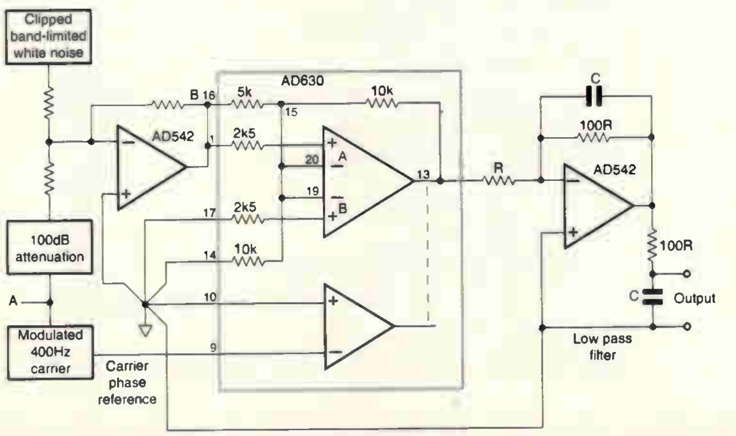


Fig. 5. This circuit when calibrated using two or more standard salt solutions, offers excellent linearity and accuracy over a very wide range of humidity.

Fig. 6. Based on the Analog Devices AD630 modem chip, this synchronous detector can extract a wanted signal buried in noise.



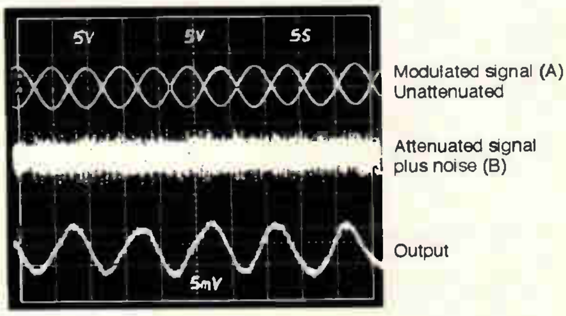


Fig. 7. The lower trace shows the wanted signal has been successfully recovered from the very noisy middle trace.

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LETTERS

Letters to "Electronics World" Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Understanding capacitors

Many thanks for Cyril Bateman's articles on capacitors. The pitfalls of misusing the multitude of different types are often overlooked.

I was particularly glad to see Cyril restating the manufacturers recommendation to use 1Ω/volt of series resistance when using tantalum electrolytics to decouple power rails. Many engineers ignore this and I have seen the resulting holes burned in the pcb by short circuit capacitors – especially on pc motherboard +5V rails which can easily supply 20A of current.

Manufacturers supply fused devices for this application but very few engineers realise why they are necessary and opt for the cheaper unfused alternative.

One thing I would disagree with is Cyril's statement about aluminium oxide being a semiconductor. Having worked for many years in the thick film hybrid industry, which relies on alumina substrates, I can assure him that this is definitely not the case.

I think that Cyril is confusing ionic conduction in liquid electrolytes with hole/electron conduction in solid semiconductors. Both give rise to rectifying effects and threshold voltages around 1V but they are not the same thing. Semiconductor diodes do not generate gas when conducting in the forward direction!

The manganese dioxide in tantalum capacitors is a semiconductor but that is a different story.

Chris Green
Bream
Gloucestershire

Filament failure

With reference to Ian Hickman's useful article 'The Protection Racket,' I think there is a bit more to what happens during the failure of a hot filament during warm up.

Firstly, consider an incandescent lamp or a directly heated filament in a valve. An efficient lamp design must prevent too much heat leaking from the incandescent filament. The filament is therefore rather poorly supported and is vulnerable to magnetic forces.

Many lamps use a coiled or a coiled-coil format, which may perhaps increase the magnetic effect. A mechanical shock is caused by the pulse of inrush current and the mechanical forces produced are significant in relation to the mechanical strength of the filament.

So a common failure mode is simply that the filament breaks rather than melts. Quite often though, the breakage leads to a loose end of the broken filament touching the wire on the other side of the circuit, causing finally an exciting meltdown.

As a second example, consider an indirectly-heated cathode in a thermionic valve. In the heyday of thermionic valves it was a commonly stated belief that the tendency for the heater to fail at the time of switch on was 'because the cold heater has a low resistance which allows an excessive *inrush current* which then overheats the heater'.

This is self contradictory. If its cold it isn't overheating and if it is hot there is no excessive current. A more satisfactory explanation is as follows.

The cathode is heated to make it hot enough to emit electrons, but with as little power as possible. Therefore the thermal leakage paths are minimised.

The most notable path is via the connecting straps which are always remarkably thin, whether the ends of the heater itself or a separate strap. This thinness appears most obvious at the weld to the more substantial wire that connects eventually to the external pin.

The useful part of the heater is tucked inside the cathode cylinder. It has considerable thermal inertia and so can not heat anywhere nearly so rapidly as the little connecting straps.

As you switch on, there is usually a very evident bright light from these straps. They usually become almost as incandescent as a lamp. During that brief period, the bulk of the heater is still very cool in comparison so that the total circuit resistance is small and the inrush current large.

Not surprisingly a failure due to melting virtually always occurs at the straps and never the heater proper – unless of course there was a serious flaw in its manufacture.

Finally though, as Ian Hickman implies, there must also be an effect of sudden thermal changes, resulting in changing mechanical stresses. I wonder if any reader who designed such devices and therefore has more specialist knowledge, would be kind enough to offer some further comments on the subject.

Bob Pearson
Bourne
Lincolnshire

German satellites

To answer Andrew Emmerson's query in your August issue, the German project that I mentioned in my 1945 article referred to the ideas which Dr Wernher von Braun and his colleagues were fond of discussing while they were developing the V2 missile, *viz.* multi-stage rockets, and their extension to artificial satellites.

This was one of Himmler's excuses for arresting von Braun on the not altogether inaccurate grounds that he was more interested in reaching the Moon than London!

Even in 1945 the idea of artificial satellites was an old one, but not until the advent of television was its most important commercial application obvious.

Sir Arthur C Clarke CBE
Sri Lanka

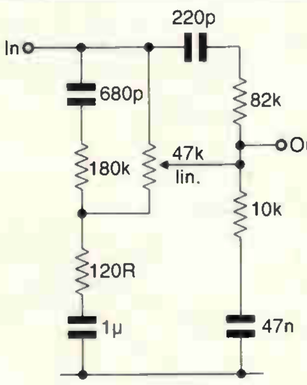
Are your ears flat?

Regarding the letter on hearing non-linearities in the June issue, for several years I have been incorporating the circuit shown for a passive 'presence' volume control into my audio systems. It came from an SGS-Fairchild design note dated 1968.

I have found it moderately useful when listening to music at low volume through loudspeakers; however when using headphones, the effect is quite dramatic.

Use of the normal volume control causes the sound to go 'thin', but if the presence control is used to reduce the volume, the effect is to the bundle the sound source up and transport it off into the distance.

Alan Frobisher
Ely
Cambridgeshire



Simple loudness control has a dramatic effect when used with headphones.

Gain-stage comments

I found the article 'Gain Stage Investigations' by John Linsley Hood difficult to reconcile with my own amplifier philosophy and investigations. After careful consideration I offer the following comments.

On page 579, the amplifier stages are consistently shown without a Miller dominant pole capacitor, although this normally determines the open-loop gain of an amplifier at a given frequency. It is not clear if this is a deliberate avoidance of the normal transconductance-transresistance configuration.

In reality, Miller capacitance is always present – even if it is just the internal C_{bc} of the voltage amplification stage transistor. At frequencies where it is effective, ie above the dominant pole, the presence of this shunt feedback path completely changes the operation of the two stages. Two cascaded voltage amplifiers become a transconductance-transresistance architecture. Here, the input pair operates as a transconductance stage, i.e. voltage-in, current-out, driving a virtual-earth voltage amplification stage input. This is the case in at least 99.99% of all power amplifiers.

Without a local shunt feedback path around the voltage amplifier stage, the input stage must work as a voltage amplifier. This raises problems at once with the extra time-constant at Tr_1 collector. There is now no pole-splitting effect, leading to trouble with high-frequency stability.

The absence of local negative feedback around the voltage amplifier stage prevents both linearisation of the voltage amplifier stage. It also reduces its output impedance to render it immune to the non-linear loading of the output stage.

In these model amplifiers the 2.7kΩ collector load is much too low for realistic gain results. The loading presented by an emitter-follower stage driving 8Ω varies between 10kΩ and 80kΩ over the output range. Such non-linear loading has to be addressed for good thd performance to be achieved, and local shunt feedback around the voltage-amplifier must be the most direct method.

Since the supply voltages are not given – and this is an unfortunate omission, as it directly affects voltage-amplifier stage linearity – it is not possible to determine if the input pairs are balanced. If you assume that Fig. 4 is balanced, then the rails come out at ±17V. This is fine for op-amps, but far too low to give realistic harmonic distortion results for power amplifiers.

Slew-rate limiting is not an inherent design problem in power amplifiers. A rate ten times in excess of that required by any conceivable audio signal is easy to obtain.[1]

On page 580, the amplifier circuits shown have no ac feedback. They are apparently intended for the direct measurement of open-loop gain. I tried it, but this certainly doesn't work for Fig. 4, which after it has settled – which takes forever – merely oscillates at some low radio frequency.

Discouraged by this, I did not build the other versions, as it seems unlikely that the direct measurement of 115dB of open-loop gain is in any way possible. It is far more practical to run Fig. 4 closed-loop at +27dB gain and measure the error voltage between the two inputs, as described in reference 2.

This worked beautifully and yielded a gain of about 80dB or 10000 times, not 4412× as quoted. Such "accuracy" is misleading because the gain varies with Tr_3 beta. The four devices I tried for Tr_3 gave a variation of ±5%.

In a real power amplifier, with a closed-loop gain of +27dB, 30dB of negative feedback at 20kHz is both safely stable and adequate for a 'Blameless' thd performance.

Thus the maximum open-loop gain required at 20kHz is 57dB. If this is allowed as usual to increase at 6dB/octave as frequency falls to 1kHz, by which point the distortion of a Blameless amplifier has disappeared into the noise floor around 0.0006%, the open-loop gain is 83dB, and it is difficult to see that more than this will ever be required for distortion reduction.

However, maximum global feedback is also desirable at lower frequencies because it maximises power supply rejection ratio.[3]

The lowest frequency of interest is ripple at 100Hz – another 3.3 octaves down – giving a maximum open-loop gain of 103dB. This implies that the dominant pole is below 100Hz. As a result, the gains quoted in the article are pretty much for dc only. In particular they say nothing about the closed-loop distortion because over most of the audio band the negative feedback factor is set by Miller capacitor C_{dom}.

On page 581, when discussing how negative feedback reduces distortion, John ignores the fact that in real amplifiers the open-loop gain, and hence the negative-feedback factor, is a strong function of frequency. In a Blameless amplifier the 8Ω thd is mostly crossover distortion, replete with high-order harmonics. Each harmonic is only reduced by the amount of negative feedback at the frequency of that harmonic.

This complicates the calculations to the point where it is much quicker to build a design and measure it. The Spice simulators I have used do not have enough numerical resolution in the FFT post-processor to allow meaningful results for closed-loop distortion.

In Fig. 11b) the 100Ω resistors shown in the driver emitters make proper operation of this circuit impossible. The open-loop distortion may well be as high as 1.1% at 5V rms. Without these unwanted resistors, I measured a thd of 0.014% at 28V rms into 8Ω.

John asks, on page 582, what distortion can be expected from these amplifiers, but never answers the question and gives no distortion data for the small-signal stages at all.

This left me wondering if something was missing. John states that distortion due to curvature of input-stage characteristics will be very small, but this becomes less and less true as frequency rises, and the error-voltage increases, until at 20kHz input-pair distortion can easily dominate.

Referring to page 583, since as far as I am aware, I am the only person who has ever written anything on the problems of worse thd with heavier loading, and the challenge of load invariance, I must admit that I am not quite clear why large-signal-non-linearity should be called the "Sandman Effect". And no, I don't propose to call it the "Self Effect" either. "Beta-droop distortion" would be nicely descriptive.

I am aware that John has written that there are better compensation schemes than the dominant pole method. Many people have said this, and it may even be true.

However no compensation at all is shown, which is a great pity as the method selected powerfully affects thd. If the whole article is predicated on some alternative compensation scheme, this should have been stated.

I was concerned that the remarks John makes at the end of his article indicated that he had tried and failed to make sub-0.001% amplifiers using my design methodology. This would be surprising as it is both totally reliable and fairly straightforward. I hastened to invite him to Potter's Bar to inspect a small test amplifier I keep handy which gives 0.0007% at 1kHz – though that is mostly noise, of course.

In my experience such low thd levels cannot be measured with anything less than an Audio Precision *System-1*.
However, John assured me that this is in fact a reference to certain commercial equipment that fails to meet its published specs.

Doug Self
London

References

1. Self, D, *Audio Power Amplifier Design Handbook*, Chapter 7, Newnes. ISBN 0-7506-2788-3.
2. Self, D, 'Distortion In Power Amplifiers 1. Open-loop gain tests,' *Electronics World*, Aug. 1993, p. 630.
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Sweeping back again

Further to my article 'Sweeping back' in the May issue, number of readers kindly wrote with details of the sanatron, phantastron and other related circuits.

Clearly the combined knowledge of *Electronics World* readers forms a massive pool comprehensively covering electronics from its infancy to the present time.

There is evidently some minor variation in the nomenclature regarding these circuits. However there is a general agreement that the phantastron is basically the same as the Miller-transitron of Fig. 6 of my article, but with the addition of diodes to define the start and end voltage of the sweep more closely, and also for the injection of trigger pulses.

The sanatron was commonly used as a delay rather than sweep generator. It adds another valve to the circuit, the additional gain permitting faster operation by the use of a reduced value of the timing resistor.

Here is a list of references for those of you who want to know more. Though these books will doubtless be out of print, they will nonetheless almost certainly be available as the result of a library request, given patience.

Since writing the article, I have also discovered, lurking at the back of one of my bookshelves, a copy of Electronic Circuits, T L Martin Jr, Prentice-Hall, 1959. Promisingly, its index lists the phantastron, sanatron and sanaphant, but on turning to the reference section, disappointingly, only the phantastron is in fact covered.

Ian Hickman
Waterlooville
Hampshire

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Wire with Litz

I read Ian Braithwaite's letter in the July issue about variable-frequency oscillator microphony. Concerning this I have the following.

Wiring it with Litz wire is better than using solid wire. You can make

Continued over page

a bicycle spoke vibrate on the edge of your desk, but with a peace of Litz wire this will not work.

Secondly, the smaller the variable air capacitor the better. Large, thick air capacitor plates are poor. It is essential that critical equipment is cushioned well with foam rubber or something similar.

It is clear that the supply ripple requirements are very high – at least 0.01%. Supply ICs can achieve this, but ultimate care must be taken to make the best possible ground connection to supply ICs.

Wim de Ruyter
Oudkarspel
The Netherlands

Radiation answers

In the May 1998 issue, an article called 'Versatile radiation meter' appeared on pages 402-406.

Having been involved with a few nuclear in-reactor measurements and the consequent radiation controls etc I was puzzled by the motivation of the above paper. In it, the potential production of gamma radiation by high voltage flashes is hypothesised.

This is very improbable in a standard environment, unless very high voltage flashes were produced in-vaccuo by means of very special triggering or by break down of the device.

In any case it is practically impossible to arrive at gamma rays. These are generally produced by decay of radioactive elements, other nuclear reaction, or by the 'synchrotron radiation.'

As I recall, the range of wavelength involved are 0.005 to 1.4 ångstrom for γ-rays and 0.1-100Å for x-rays.

As an example, one of the shortest x-ray wavelengths, at 0.137Å, comes from 83Bi, which is equivalent to about 90keV. This does not mean that this emission is excited by only 90keV, since this is the 're-entry' energy of the emitting electron.

To excite this deep orbit of the Bi atom, however, all the other electrons need to be pulled away first, for example by a suitable bombardment by other high-energy electrons. This explains the very high energy needed.

To produce shorter wavelengths than x-rays it is necessary to interact with the nucleus of atoms: a task that a simple discharge cannot perform.

X-ray production is also improbable since during normal discharges that are not in a vacuum, it is only possible to excite the more external electrons of the element involved, for example platinum discharge electrodes, or/and the surrounding gas. At best, this gives rise to short ultra-violet radiation. This does not mean that precautions are useless, since in high-voltage vacuum devices like post accelerated cathode-ray tubes, very high voltage rectifiers, transmitting tubes etc, some x-rays can be generated. But these are 'soft' x-rays and therefore easily screened off.

Because of the potential danger, measurement is necessary to evaluate each case. But measurement is not easy. I was puzzled by the choice of Geiger-Müller counters as measuring devices, since they are neither particularly sensitive nor reliable. This is one of the oldest radiation measuring devices.

For this purpose, specialised solid state devices were available twenty years ago, albeit costly. I imagine that several more are commercialised now.

Of the long-established devices, the ionisation chamber would have been a better choice, and it would have simplified the associated electronics.

In the early days, the design was somewhat difficult as electrometers and large amplification were needed to pick up the tiny currents produced by the ionisation chamber. Today the design should be easier.

This ionisation chamber has the added bonus that it can be self made with simple means.

As found by the author of the article, 'sources' of radiation to test the apparatus are infrequent. As noted in the article, the gas mantle is one since thorium dioxide – a naturally radioactive element – is one of its components. Luminous watches are lit by a low energy emitter, which cannot penetrate outside.

Another natural source is granite, which often contains small quantities of uranium. But you have to search for a good sample, or find information on where uranium-bearing granite is sited.

Calibrated sources can be obtained from specialised laboratories, but they are probably available only to professionals. If uncalibrated, therefore, such an instrument will be measuring an unknown amount of radiation in all cases. In addition, its directivity will be uncertain, making all the guesses very unrealistic.

Having said that, I appreciated the interesting design of the electronics.

Dr G. Imarisio
Menton
France

Pot luck

Regarding 'Pot problems' in the July letters column, the value of both the volume and balance controls on the *Leak 70* amplifier is 20kΩ log, not 20Ω. I have a copy of the circuit diagram.

S M Jacovides
London

What Microsoft monopoly?

I read the Comment on page 539 of the July edition with some surprise. One could easily assume from the tone of this piece that the author had a distinct bias against Microsoft Corporation in general, and Windows in particular.

There is no monopoly in the operating system market: the availability and continued development of OS/2, Mac OS, Linux, etc bears testament to this. The perceived monopoly of Windows stems from a variety of sources, viz:

- In the late seventies and early eighties a plethora of incompatible systems existed. Then IBM came along with its pc. The excellent marketing ploy of licensing the technology to system designers meant that the IBM pc rapidly became accepted as a standard as industry adopted the new IBM product.

IBM then contracted Microsoft to develop an operating system for its new baby. Thus came PC-DOS, and the clone-builders version, MS-DOS. The IBM/Microsoft tie-up is where the seeds of Microsoft's success were sown.

- Interest in GUI technology, started by Xerox in the US, led to the production of the Mac, and a curious product from Microsoft called Presentation Manager for DOS – a direct GUI spin-off from the new OS Microsoft was developing for IBM.

- The marketing ploy backfired, to some extent a victim of its own success. Now most pc users have a pc-clone, mostly running Windows. Users of genuine IBM machines generally use OS/2.

- The marketing success of the pc in its various forms is the opposite of the situation with the Macintosh. Visual styling and the doubtful technical advantages of an OS built as a GUI from the ground up were of no consequence to the vast numbers of pc users, who could switch to a GUI without having to buy a new machine.

This situation was made worse by the initially poor availability of business software for the Mac. Add to this the reputation of the Mac as being 'good for desk-top publishing and graphics', and you have a high-tech machine that no word-processor or spreadsheet user wanted.

Of course, this software has always been available for the Mac, but the dtp image coupled with the already vast developer effort in the pc world meant that the best business software was always available first for the pc, then 'ported' to the Mac. Naturally, most business users used pcs.

My point with all this is that technical excellence is no basis for the successful marketing of computers. People buy whatever is marketed best.

Does anybody remember the Video 2000 system from Philips? This system was far better in terms of technology and performance than either VHS or Betamax, but was let down by poor marketing.

It is pointless also to wish that the computer industry had been 'well regulated'. If this had been the case, we would all most likely still be using CP/M as the various industry members squabbled over which way was best. The type of regulation mentioned would result only in creativity stifled by the dead hand of a committee.

It is inevitable that progress results in standardisation – the factors at work in the computer industry are many and complex, but at the end of the day, it is still a customer – led industry and we have only ourselves to blame.

How could government create legislation to force developers to create applications at the same price? Different platforms present different technical difficulties to the developer. Isn't it only fair for software companies to levy charges based on technical difficulties, and also on customer demand?

Software that every one wants is always cheaper than niche software. A legislative approach like this could only result in one thing – vast increases in software prices for everyone, is this really a better situation than a so called monopoly?

Anyway, what about Sun's Java OS? This is written in the nearest thing to Esperanto for computers as it will run on any machine that has a Java Virtual Machine (JVM) byte-code interpreter.

Obviously the JVM is platform specific; but other than that code written in Java will run on any platform without modification. Perhaps this is the real way forward.

Keith W Saxon
St Helens Lancashire

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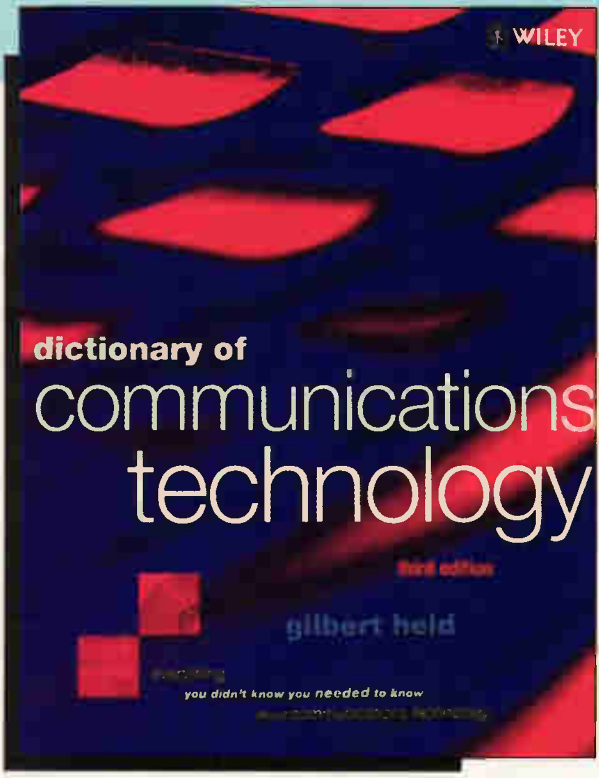

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Synthesised 50-950MHz source

Programmable via ttl logic levels, Nick Wheeler's 50 to 950MHz signal generator is simple since it revolves around a highly integrated crystal-controlled synthesiser chip.

This design uses the Synergy *SY89430V* synthesiser to provide any crystal-referenced frequency from 50MHz to 950MHz.

Using a 16MHz crystal, the frequency can be selected in 2MHz steps. Internal frequency division by 1, 2, 4 or 8 can be selected, providing reduced coverage in smaller steps. Any crystal in the range 6.26MHz to 25MHz can be used. The *SY89430V* is specified up to 950MHz, but the three samples I have had work up to 1008MHz at least, but not consistently.

These parts use emitter-coupled logic, or ecl, but the programming inputs operate at 3.3V or 5.0V logic levels. While I have described a free-standing source capable of driving a 50Ω load this circuit can clearly be integrated into any logic system, as a clock for example.

Using the *89430* synthesiser

A phase-locked loop operates at 2MHz, derived from a 16MHz crystal. This controls the frequency of a voltage-controlled oscillator which has an operating range from 400MHz up to the specified 950MHz.

As I mentioned earlier, this part may extend above 1GHz, but this is not guaranteed. A 9-bit ttl-level word $M_{0\text{-}8}$ sets the modulus, M, of a frequency divider in the range 250-510. With a 16MHz crystal the voltage-controlled oscillator is held at 2×*M* (MHz).

Output frequency of the device is then determined by the 2-bit word N(1,0), also at ttl level. Table 1 shows the effect of varying N(1,0). Values on M(8,0) and N(1,0) are read into the appropriate internal registers by a low-high transition of /PLOAD.

In my version of the circuit, I tie /PLOAD. on pin 7, to ground via 4.7kΩ and a normally closed press-button switch.

Table 1. SY89430's four output ranges are selected via logic levels on N_0 and N_1.

N_1	N_0	Div. ratio	Range (MHz)	Step (MHz)
1	1	1	400 to >950	2
0	0	2	240 to >500	1
0	1	4	120 to >250	0.5
1	0	8	<50 to >120	0.25

When this switch is operated the internal pull-up resistor takes /PLOAD high.

I have found that after setting in a frequency change, using this for a few moments ensures that the internal registers are set properly. The latches of the register inputs are specified as being transparent when /PLOAD is low.

No difficulty will be experienced if the output frequency is monitored as I suggest. The circuit does, however, sometimes misbehave by locking onto a wrong frequency if M settings outside the range 250-510 are applied.

Bearing in mind that the voltage-controlled oscillator runs at 2×M (MHz), settings in accordance with the table below do, however, invariably work.

There is a lower-frequency version of this part, the

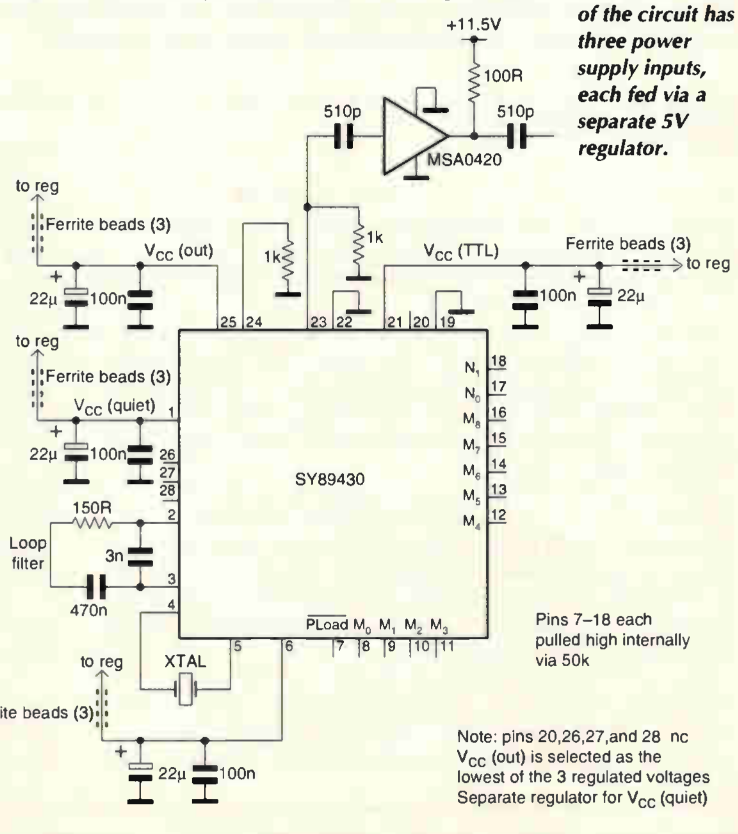

Fig. 1. Complete programmable signal source for 50-950MHz with 50Ω output. The ecl synthesiser chip at the heart of the circuit has three power supply inputs, each fed via a separate 5V regulator.

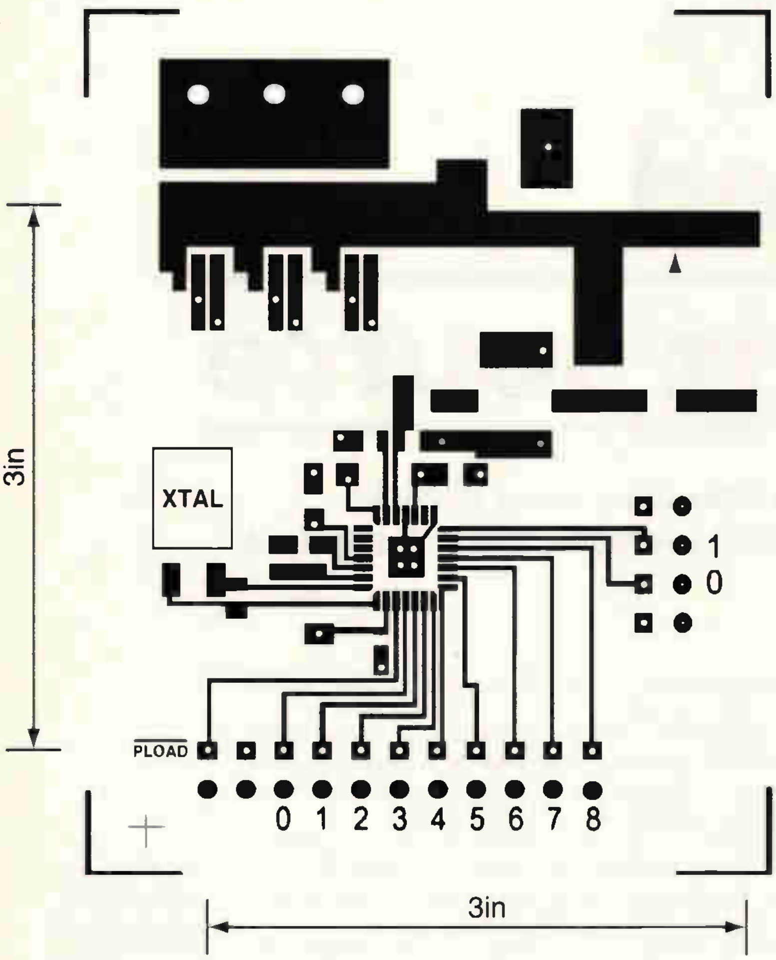

Fig. 2. Layout of the signal source is critical; this one works. The small circular dots are 1mm holes while the three holes at top left are 3mm. 15 circular blobs, right and bottom, are guides for drilling 2 mm holes. The board is connected by ribbon cable to the selector. The strands of cable pass through these holes for strain relief.

SY89429V. This is guaranteed up to 400MHz and has a divide-by-16 range selected by N(1,1).

Phase-locked loops require a filter for stability, and the three components of this are shown in **Fig. 1**.

The selected-frequency outputs are at ecl levels and have to be properly terminated. In this case, since the layout is very compact, a simple 1kΩ to ground is sufficient. One of the outputs is buffered by an *MSA-0420* MMIC to give an output of at least 1V pk-pk when terminated in 50Ω. The *MSA-0420* is a premium-grade part. Cheaper types are available.

All the remaining external parts relate to power supplies which are carefully decoupled. The supply to Pin 25 must be lower than that to pins 6 and 21.

Supply to the vco, pin 1, is separate and should be as noise-free as possible, since noise on this line is translated into frequency jitter. The requirements are met by having three separate 7805 regulators, that for pin 25 being selected as having the lowest output voltage.

Synergy parts with a 'V' part-number suffix will work with V_{CC} down to 3.3V, but I have not tried them.

Implementing the design

Circuits operating at 1GHz can be based on double-sided GRP boards such as G10. This is fortunate, since Teflon-based board is both costly and difficult to work with.

I used conventional photo-etching techniques for my prototype. These involved no more than a modest pc-compatible, Windows 95, a low-cost package called Serif Draw Plus 2 and a suitable ultra-violet exposure box.

No specialised equipment was necessary. The artwork I developed is reproduced as **Fig. 2**. One side of the board is a continuous ground plane and is not illustrated.

Tidy layout is achieved by distributing V_{CC} from the three regulators on the underside of the board. vias are created at the appropriate points using Vero pins, small areas being etched to insulate these.

If the board is to be manually prototyped, these holes can be counter-bored on the groundplane side. This avoids the need for etching on the groundplane side and also the need for registration.

The numerous earth points on the parts side are connected to the groundplane using track pins such as Maplin FL82D. Each lead from the via at each regulator output threads three

Using plccs

Plastic leaded chip carriers, or plccs, are becoming increasingly the format of choice for moderately complex ICs, i.e., those having 20-84 leads. The square design minimises the length of the connections between the actual chip and the output terminals.

Plastic leaded chip carrier parts can be mounted directly on the circuit board, using one of the many smd technologies. The big advantage of plcc technology, for development or experimental work, is that excellent smd sockets are available. These enable costly parts to be retrieved without difficulty for re-use.

Manufacturers data, such as reference 4, specify the dimensions of the necessary solder pads. But these dimensions really relate to the design of the screen-printing of solder paste for volume production. It is perfectly feasible to assemble sockets such as the 28-way RS203-9448 – as used for this design – by hand, using a fine-tipped iron and surface-mounting solder paste.

The small plastic square at the base of the socket should be removed to make access easier. This square is attached at its corners by thin plastic spokes. The material is quite soft and can be cut with a scalpel, care being taken not to deform the solder tabs.

Also take care not to deform the socket from squareness while doing this. Soldering is made much easier if a modified design of pad is used. **Figure 3** shows such a pad for the 28-way part. Dimensions for other parts can be found in the RS Catalogue.

Essentially, the pads are extended inwards by about 1mm. This provides a small area of copper to which the solder paste can be applied using a hypodermic syringe and a coarse needle. Solder paste usually comes with a thin plastic nozzle, but I find these nozzles a trifle clumsy. Note the bevelling of the corner pads.

The use of sockets creates a 'no-go' area of 0.7in square for the 28-way part. Inside this square, no parts, such as decoupling capacitors, can be mounted. When laying out the circuit, I find it convenient to mark out this square with a hairline trace. Such a trace disappears in the etching process.

I make my transparencies using a colour printer. If the trace is in blue, it is effectively transparent to the ultra-violet used for the photographic process.

Note that plcc sockets are also available for through-hole techniques. They have an array of through-pins on a 0.1in grid. But surface mounting is virtually essential for designs of this sort.

ferrite beads. There is a 22µF tantalum capacitor at each via adjacent to the four V_{CC} inputs to the synthesiser, on the groundplane side of the board.

The *SY89430V* comes in plcc and soic options. I chose the former. A note on using plcc format appears in the panel entitled 'Using plccs.' Essential decoupling components, mounted as close to the IC as the socket will allow, are 1206-format 0.1µF parts. Their earthy ends are on pads grounded via pins to the ground plane.

The three loop-filter components are also located as close in as possible. Pins 23 and 24 are grounded through 1kΩ as close in as possible, too. The square inside the plcc footprint provides ground, via four through pins in parallel, for pins 19 and 22.

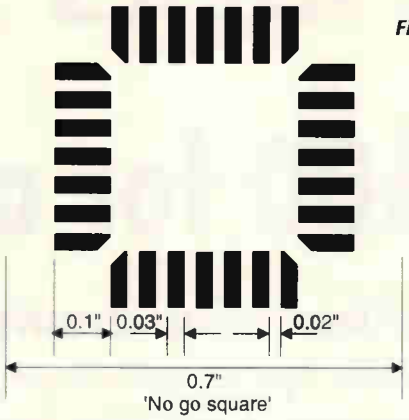

Fig. 3. Dimensions of the plcc pad.

Loading data serially

Pins 20, 26, 27 and 28 support a facility for serially loading the programming data and for some test functions. These are not used and should be left *open*.

The broad 0.11in traces associated with the MMIC are, on the 0.0625in board used, 50Ω striplines. An SMA jack is mounted on the pcb and this is connected via a length of RG405 semi-rigid co-axial cable to a jack mounted on the front panel. Including mains power supply, the whole instrument fits into a die-cast box 190 by 110 by 60mm.

The modulus M(8,0) is selected by nine small toggle switches and N(1,0) by a four-position rotary switch.

The power supply is conventional. An LM317, thermally coupled via an insulating washer to the diecast case, is set to provide 11.5V for the MMIC. This is reduced to 5V by the three regulators mentioned above.

Designer deal

Electronics World readers wanting to experiment with this design can obtain the pcb, plcc socket and *SY89430* at the special fully inclusive price of £38.95. This is an exclusive reader offer – the normal package selling price would be £70. For overseas readers, the inclusive price is £35.50 (no VAT).

Note that the package includes data sheets, design notes and other useful information on high-speed circuit layout. Please send your cheque to Nic Houslip at NJ Houslip Ltd, 16 Swinbrook Way, Shirley, Solihull B90 3LZ. Tel. 0121 733 8033, fax, 0121 733 7772, e-mail nic_houslip@compuserve.

Control and application

A feature of ttl programming inputs on Synergy ecl parts is that they are normally tied either high or low internally via resistors in the region of 50kΩ. In the case of the *SY89430* they are tied high. They can be forced low by grounding them though 4.7kΩ or less.

The simplest method of programming this part is by a dual-in-line switch to set the 'M' and 'N' inputs low as required. Some people can effortlessly do binary to decimal conversions in their head. I cannot, so I use a prescaler[2] and frequency meter to check the settings. This is less of a chore than doing the calculation, and gives one confidence that no mistake has been made.

The fact that the modulus is set by a 9-bit word makes such approaches as using bcd thumbwheel switches and an eprom to decode them into a proper form, impracticable except at prohibitive cost. I have also built a system using three cascaded LS193 up/down counters which can either be incremented or decremented one count at a time or clocked at a slew rate.

Parallel outputs from the counters form the modulus word, and leds on each line indicate the selection. This however involves ten ICs. And, naturally, the indication is a binary number.

The output is specified as a square wave of 45%-55% duty ratio, but of course on my 100MHz oscilloscope, even at the lowest specified selectable frequency using a 16MHz crystal looks very much like a sine wave.

Rise and fall times are specified as 300-800ps. Setting the frequency to an arbitrarily-chosen 53.5MHz yielded harmonics detectable on my home-made spectrum analyser[3] right up to 850MHz.

The oscillator circuit calls for a series-resonant crystal. If a crystal calibrated for parallel resonance is used, it will work just as well, but the frequency will be slightly low.

Assuming my frequency meter is accurate, a selected frequency of 125MHz measures out at 124.941MHz. This is 472ppm low. In many applications though, such an error is irrelevant.

I set the frequency to several quiet points in the vhf broadcast band. A suitable receiver was fully quieted at a distance of several metres. There was no perceptible noise. I think this proves that there is no jitter in the phase-locked loop.

The synthesiser IC consumes just under a watt at 5V. It gets quite hot. A 24-hour soak test at an ambient temperature of 20°C led to a final air temperature inside the box of 40°C.

Operating outside the limits

Guaranteed frequency limits for the *SY89430V* are 50MHz to 950MHz. These are readily achieved.

At the lower limit, which is obtained in the divide-by-eight mode, the waveform is a fair approximation to a square wave. Lower values of M can be selected, operation down to 48MHz being possible. However, frequencies as low as this are easily generated by other means.

I have found that 973MHz is the highest frequency at which this part can consistently be asked to operate, although I have sometimes achieved 1008MHz.

In summary

The simplicity and low parts-count of this useful signal source are attributable to the use of emitter-coupled logic. ■

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Technical support

The circuit and much useful application data is fully set out in reference 1, which can be obtained gratis from Synergy.[1] The company has a Website on http://www.synergysemi.com.

The specialised parts for this design are not currently available in small quantities from any usual suppliers.

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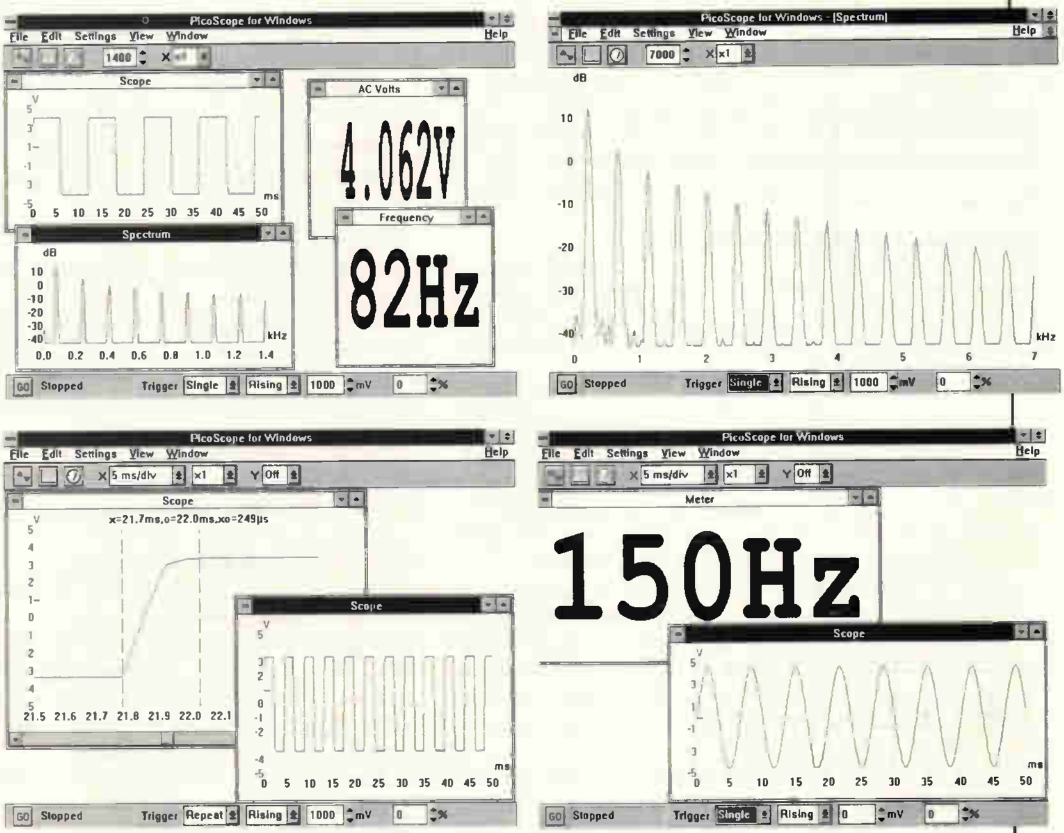
The best ideas are the ones that save readers time or money, or that solve a problem in a better or more elegant way than existing circuits. We will also consider the odd solution looking for a problem – if it has a degree of ingenuity.

Your submission will be judged on its originality. This means that the idea should certainly not have been published before. Useful modifications to existing circuits will be considered though – provided that they are original.

Don't forget to say why you think your idea is worthy. We can accept anything from clear hand writing and hand-drawn circuits on the back of an envelope. Type written text is better. But it helps us if the idea is on disk in a popular pc or Mac format. Include an ascii file and hard-copy drawing as a safety net and please label the disk with as much information as you can.



Turn your PC into a high-performance virtual instrument in return for a circuit idea.

The ADC200-50 is a dual-channel 50MHz digital storage oscilloscope, a 25MHz spectrum analyser and a multimeter. Interfacing to a pc via its parallel port, ADC200-50 also offers non-volatile storage and hard-copy facilities. Windows and DOS virtual instrument software is included.

ADC42 is a low-cost, high-resolution a-to-d converter sampling to 12 bits at 20ksample/s. This single-channel converter benefits from all the instrumentation features of the ADC200-50.

Low-battery voltage detector draws a mere 0.3μA

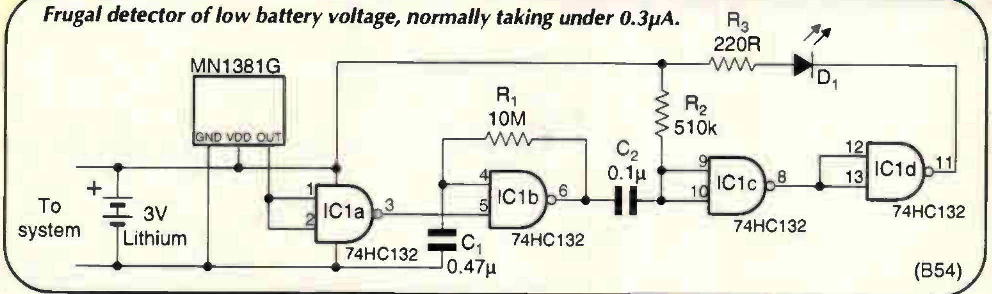
ADC42 Winner

While low-voltage detectors are worthwhile for many battery-powered devices, it is not helpful to have the detector hogging more than its share of current and thereby reducing battery life. This one draws less than 0.3μA.

The circuit shows a 3V lithium battery output being monitored by a Panasonic *MN1381G*, the output of which is normally high, forcing IC_{1B} to stay high. If the battery voltage falls below the threshold of 2.5V, the *1381* output goes low and allows IC_{1B} to oscillate with a 5s period. Each negative-going edge of the oscillator output is differentiated in C_2R_2 and the output at IC_{1D} drives the led.

As an example of the effect on a typical circuit, a device designed to use a 500mAh lithium battery for 24 hours per day for two years will have its battery life reduced by about 1%.

Frugal detector of low battery voltage, normally taking under 0.3μA.



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Torrance
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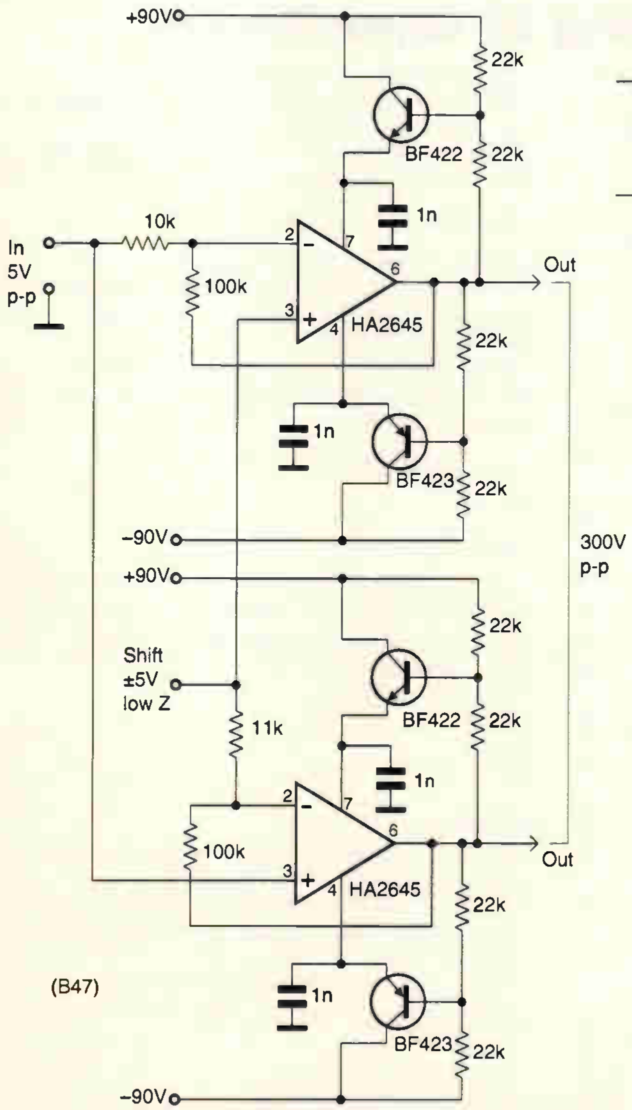
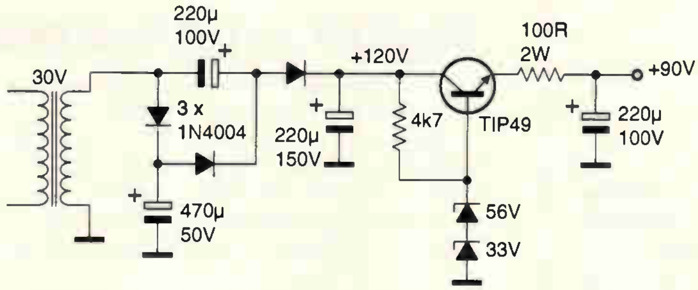
B54





With suitable supplies, this deflection amplifier puts out up to 300V pk-pk at low frequencies.

Oscilloscope deflection amplifier

Depending on the supply rails used, this simple, linear and versatile amplifier will produce up to 300Vpk-pk at low frequencies, having a gain of 20 from a 15Vpk-pk input.

The Harris *HA-2645* is probably the best choice in this circuit. Current drain is ±15mA from 90V stabilised rails, obtained from 30V windings and positive and negative voltage triplers and a series transistor with a zener reference. The 100Ω, 2W resistor protects the transistor during short-duration faults. Only one positive supply is shown, the negative using a *2SB546*

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Further reading

Burr Brown. Designing with op-amps. McGraw-Hill.

ADC200 Winner

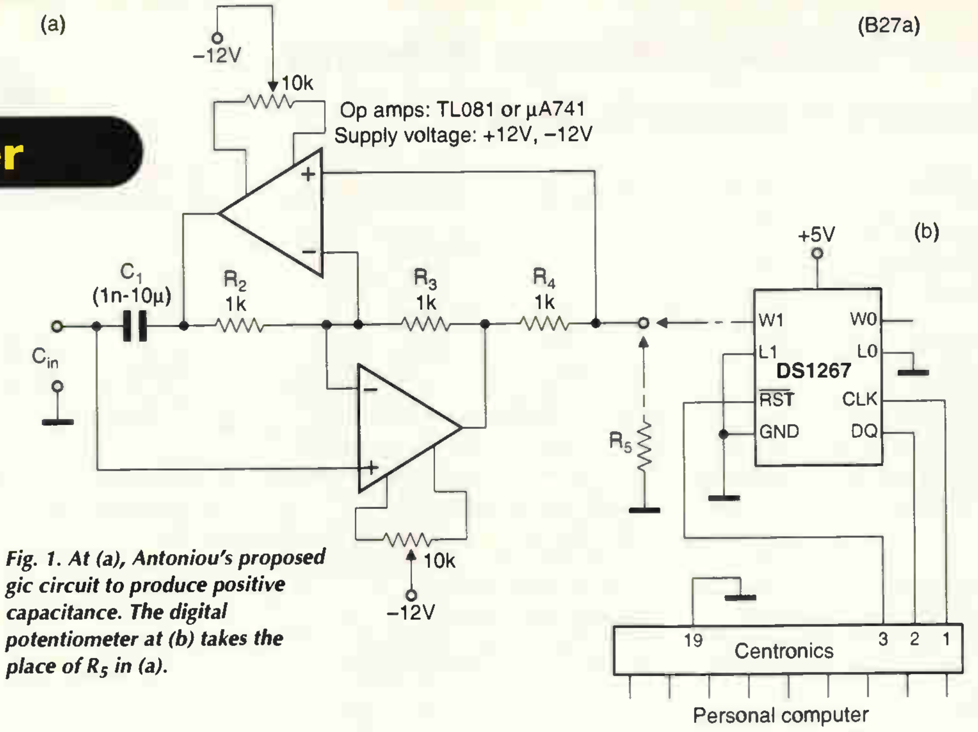


Fig. 1. At (a), Antoniou's proposed gic circuit to produce positive capacitance. The digital potentiometer at (b) takes the place of R_5 in (a).

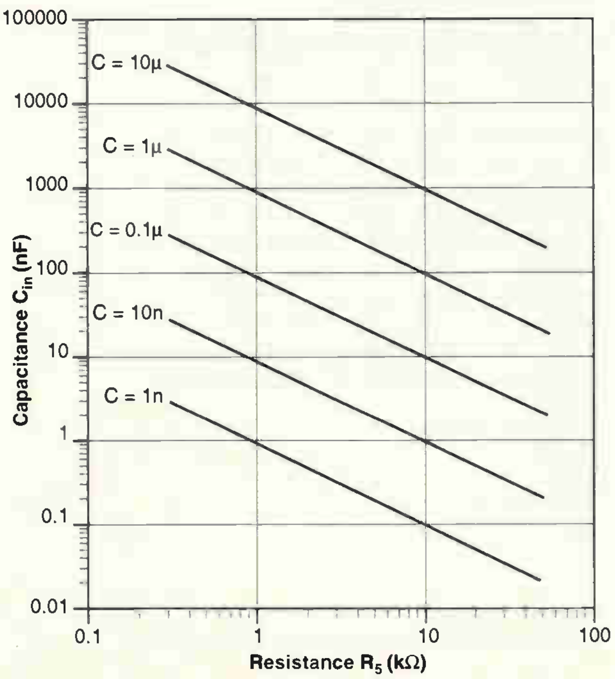
Digital programming of capacitance

Variable capacitance proposed by Dunn[1] and a development described as bipolar programmable capacitance by A R Al-Ali and M T Abuelma'atti[2] are highly sensitive. The arrangement described here , using the generalised impedance converter circuit by Antoniou[3], produces a positive capacitance with a sensitivity of unity.

In the circuit of **Fig. 1**, input capacitance is determined by

$$C_{in}=C_1R_2R_4/R_3R_5 \qquad (1)$$

Fig. 2. Effective input capacitance for varying values of C_1 against the value of R_5 and the digital input to the DA1267 from the pc.



Half of the dual digital potentiometer *DS1267/50kΩ* simulates R_5, control being applied over three wires \RST, DQ and CLK from a pc, the resulting resistance in ohms between pins W_1 and L_1 being calculated by

$$R_5=N(50000/256)+300$$

in which N is an integer between zero and 256 placed in the *DS1267* register by the pc. **Figure 2** shows the theoretical result; the largest value obtained was 2000pF.

Using both halves of the *DS1267*, the circuit may be used to tune biquad filters, the resonant frequency of which is,

$$\omega_0\Rightarrow 1/\sqrt{(C_aC_bR_aR_b)}.$$

and

$$Q\Rightarrow\sqrt{(C_a/C_bR_aR_b)},$$

C_a and C_b being connected to W_0/L_0 and W_1/L_1 respectively. If C_a/C_b is kept constant, ω_0 may be varied while Q remains constant.

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References

1. Dunn, J. 'Vary capacitance to positive or negative,' *Electronic Design*, Vol.5, 1991, p. 113.
2. Al-Ali, AR and Abuelma'atti, MT, 'Bipolar programmable capacitor,' *Electronics World and Wireless World*, July, 1995, p. 602.
3. Antoniou. A, 'Realisation of gyrators using operational amplifiers,' *Proc. IEEE*, vol. 116. 1969, p. 1838.

Testing ignition coil and plugs

To remove them from one's list of suspects, this circuit will test both ignition coil and sparking plugs outside the car.

When S_1 connects the mains, C_1 charges through the variable chain, eventually causing Tr_1 to conduct, whereupon the relay operates, contact A closes and the capacitor discharges rapidly, deactivating the relay. The outcome is that the relay opens and closes its contacts at high speed.

As contact B opens, the field of the ignition coil collapses and generates the high voltage for the spark. Adjustment of the variable resistor varies the spark rate.

The two rectifiers avoid loading of the relay circuit by the ignition coil.

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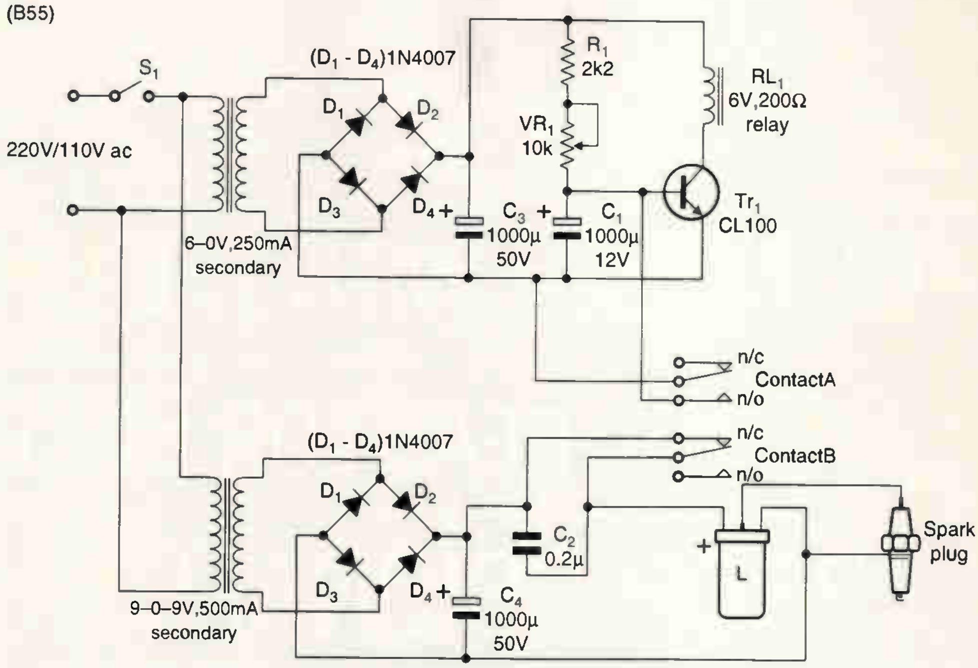
Madras
India
B55

Establish the health or otherwise of an ignition system without flattening your battery.



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HP Frequency Counter type 5340A - 18GHz £800.
HP 8410-A-B-C Network Analyser 110Mc/s to 12 GHz or 18 GHz - plus most other units and displays used in this set-up - 8411a-8412-8413-8414-8418-8740-8741-8742-8743-8746-8650. From £1000.
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Marconi **Microwave** 6600A 1 sweep osc., mainframe with 6650PI - 18-26.5 GHz or 6651 PI - 26.5-40GHz-£750 or PI only £600. MF only £250.
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Gould J3B test oscillator + manual - £150.
Tektronix Mainframes - 7603-7623A-7613-7704A-7844-7904-TM501-TM503-TM506-7904A-7834-7623-7633-7844-7854-7104.
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Simple parallel-to-serial conversion

Eight-bit parallel data is converted to one start bit, one stop-bit RS232 form by this interface. It can be a part of any programmable logic device, epld, fpga, etc., and it can be used to allow a pc to read eight parallel lines via one of its com ports.

Other than setting the bit rate, no initialisation is needed. The bit rate is equal to one clock period. Bit rate divisor 'B' can also be used to setting the bit rate divisor on the pc using 1843200/(16B).

It is possible to program the pc for any bit rate by putting the corresponding divisor value in 16-bit format using statements in turbo-C as given in the List for COM1.

Data transmission starts on the first leading edge clock after the leading edge of LD, which can be further controlled by pc or some other control. The pc reads the data via the statement, inport (0x2F8):

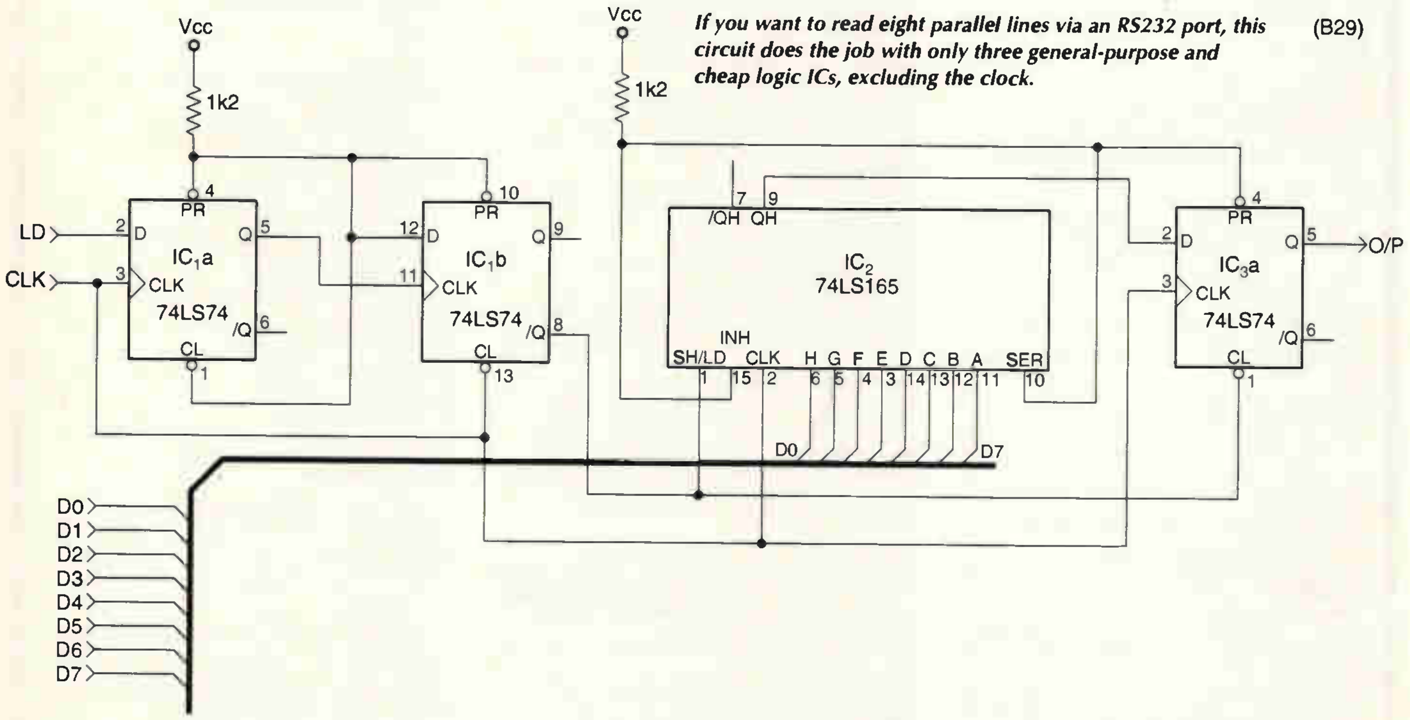
The timing diagram shows output for decimal 6 and 85 at $D_{7...0}$.

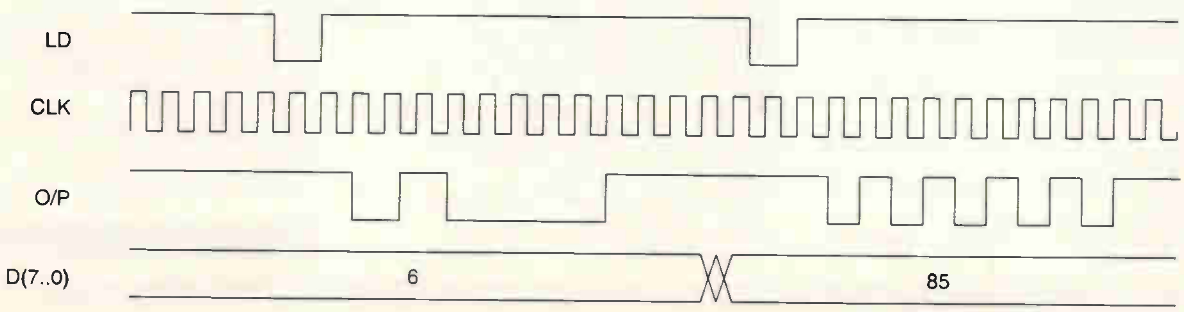
Vijayan Pillai
Kerala
India
B29

List. Programming the pc's com port bit-rate setting in turbo C.

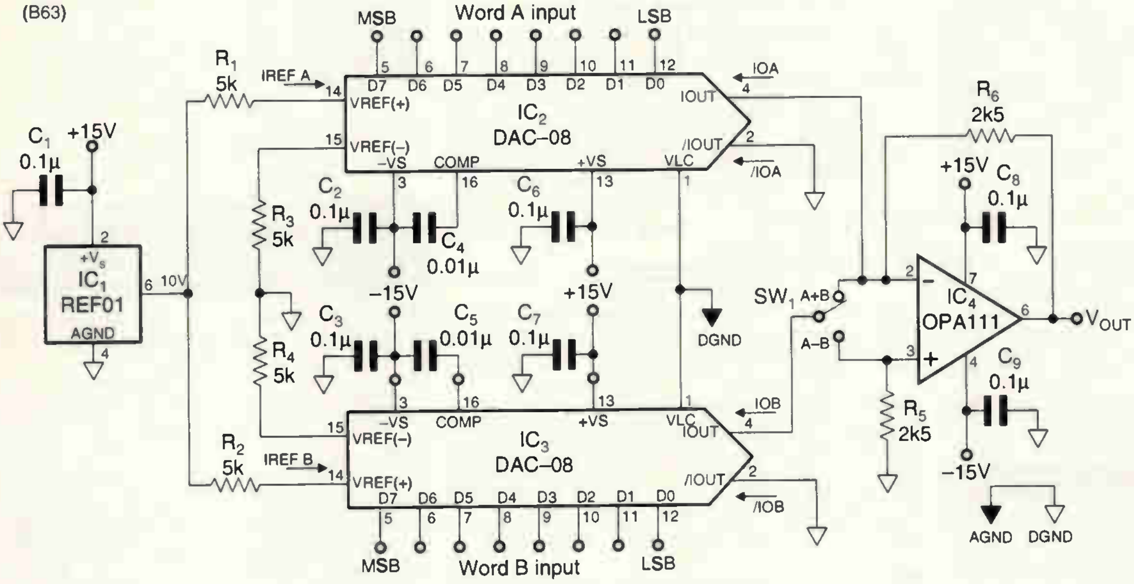
```
outport (0x2FB,131)    ;/*2F8 for baud setting */.
outport (0x2F8,0xXX)   ;/* LSB byte of divisor*/.
outport (0x2F9,0xXX)   ;/* MSB byte of divisor*/.
outport (0x2FB,3)      ;/* 2F8 for transmission*/.
```

If you want to read eight parallel lines via an RS232 port, this circuit does the job with only three general-purpose and cheap logic ICs, excluding the clock. (B29)





(B63)



Neither digital ics nor their power supply are required in this analogue-output binary adder and subtractor.

Binary adder and subtracter gives analogue output

To obtain an analogue output from the algebraic addition or subtraction of two digital inputs the usual method involves the use of several digital ics followed by a digital-to-analogue converter.

The eight-bit circuit shown totally eliminates digital ics and their power supply; it needs only four ics and the output is delayed only by the 85ns settling time of the d-to-a converter and that of the op-amp.

A 10V reference provides current for both multiplying d-to-a converters, so that

$$I_{refA}=10/R_1=2\text{mA},$$

and similarly for I_{refB}.

Output currents of the converters $I_{oA/B}$ are controlled by the binary inputs to the converters and the reference currents, so that

$$I_{oA}=I_{refA}(N_A/2^n),$$

where n is the number of bits in the binary word and N_A lies between 0 and 2^n-1, depending on the input word.

Setting switch S_1 to its position (A+B) gives the expression for output voltage,

$$V_{out(A+B)} = I_{oA}\times R_6 + I_{oB}\times R_6$$
$$=I_{refA}\times(N_A/2^n)\times R_6+I_{refB}\times(N_A/2^n)\times R_6.$$

With the switch in the A–B position, the above becomes a subtraction, assuming that $R_5=R_6$.

For the values $I_{refA/B}$=2mA, $R_{5/6}=2.5k\Omega$ and n=8,

$$V_{out(A+B\text{ or }A-B)} =2\times2.5(N_A\pm N_B)/2^n$$
$$= 5/256(N_A\pm N_B)/2^n.$$

V Manoharan
Naval Physical & Oceanographic Laboratory
Kochi
India
B63

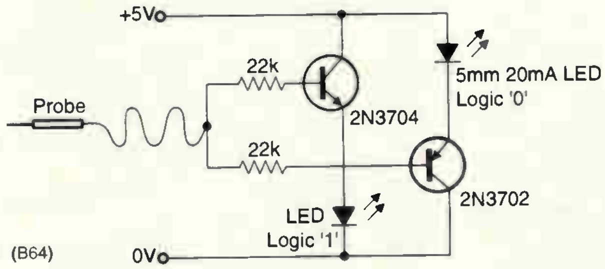
Circuit board tester

This little circuit indicates the basic integrity of a 5V printed board, detecting 0V, 5V and floating parts.

If the probe is floating, as it would be on a broken track, then both leds barely light up, since there is no current to drive the transistors, but if the probe touches 0V or 5V one or other lights. I have not tried it, but it may be that a digital signal would light them in proportion to the mark:space ratio.

The circuit is cheap enough to incorporate on a board permanently for fault finding.

John Farbrother
Walsall
Staffordshire
B64



(B64)

They don't often come much simpler than this. A circuit to detect 0V, 5V or a broken track.

More circuit ideas on page 884

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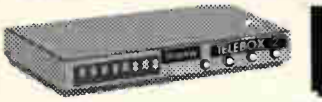

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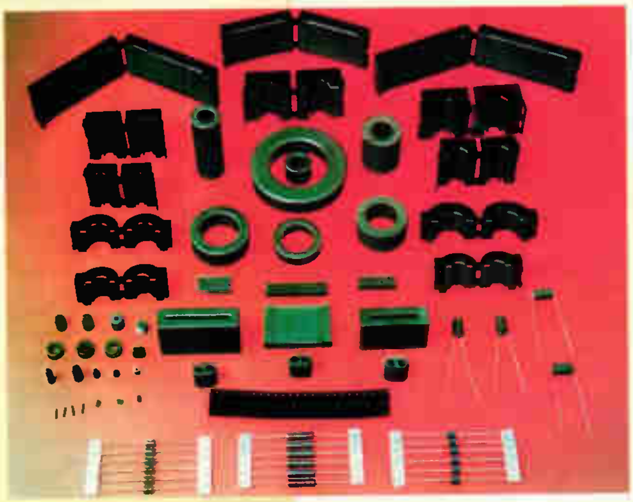
AMP. Tel., 0181 954 2356; fax, 0181 9547467.
Enq no 501

Ferrite designers' kit. Samples of more than 150 different forms of ferrite core are contained in the Fair-Rite *Omni* kit, which provides a rapid solution to many problems of interference on signal lines. There are slugs and beads, flat and round cable suppression cores, connector suppression plates, multi-aperture types, discs, toroids and bobbins. A point to note is that, should you become carried away and use up all the samples of any of the types, they will be replaced free.
Schaffner EMC Ltd. Tel., 0118 977 0070; fax, 0118 9792969.
Enq no 507



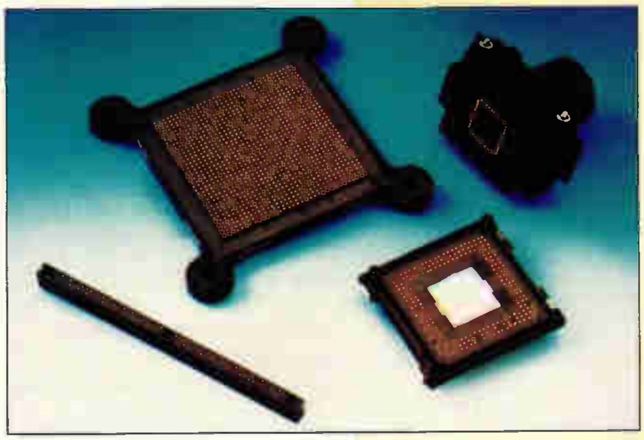
Switching DIN connectors. 96-way DIN connectors by Elco keep 10 of the phosphor-bronze contacts closed in the normal state to maintain contact and allow daisy-chain signalling across a VME bus when a card is not in position. When a card is inserted, its pins open the contacts, the card operates and maintains bus integrity. Connectors are rated at 350V dc/ac peak and 3A; minimum lifetime being 400 insertions and extractions.
Hawnt Electronics Ltd. Tel., 0121 7843355; fax, 0121 783 1657; web, sales@hawnt.co.uk.
Enq no 502

Data converters

Audio d-to-a converter. Asahi Kasei's *AK4350* is a low-power delta-sigma converter meant for use in portable audio equipment. Sampling rate is 8-50kHz and there is a post filter and single-ended output buffer. The multi-bit $\Delta\Sigma$ technique is responsible for a dynamic range of 90dB and there is a 20kHz ×8 finite impulse response interpolator with a ripple of ±0.06dB; stop-band attenuation is 43dB. Soft mute is provided on-chip.
Asahi Kasei Microsystems Co., Ltd. Tel., 01923 226988; fax, 01923 226933.
Enq no 504

Discrete active devices

500mW in SOT323. Zetex claims to have the first high-performance bipolar transistors in the SOT323 package. Super323 n-p-n and p-n-p devices in the *ZUMT* range handle 1.5A continuously and exhibit a $V_{CE(sat)}$ of 0.18V for a 1A collector current and 10mA of base drive. A full range of components in this package will include rf, avalanche, medium-power and switching transistors.
Zetex plc. Tel., 0161 622 4422; fax, 0161 622 4420; web, www.zetex.com.
Enq no 505



Displays

High-contrast, 15in monitor. Panasonic's *PanaSync S50* 15in crt monitor uses a new type of phosphor layer of Crystal Pigment Phosphor and the company's own screen coat A-AGRAS. The result is claimed to be a reduction in reflections and sharper images, since the ambient light is "trapped" in the layer. Resolution is 1280 by 1024. refreshed at 75Hz, but 1024 by 768 is recommended for the 15in size. The display supports VESA DDC1/2B standards for Plug-and-Play working and, unusually, there is a degauss button.
Panasonic UK Ltd. Tel., 0500 404041; web, www.panasonic.co.uk.
Enq no 506

Filters

Feedthrough filters. *SFNO* feedthrough electromagnetic interference filters by Syfer screw into place and have a diameter of 3.6mm, so that the mounting pitch is only 3.8mm. Available in values from 10pF to 10nF, their voltage rating is 500V while their current handling is 10A and temperature range –55°C to 125°C.
Syfer Technology Ltd. Tel., 01603 629721; fax, 01603 665001.
Enq no 508

Hardware

Fan mounts. SRS has a new range of subrack front panels in 3U and 6U heights and 21HP, 42HP and 84HP widths. The panels are designed to take one, two or four 90mm fans (3U) or double the number in the 6U versions, a blanking plate being available to cover unused positions. There are also intake panels punched with ventilation slots, which may be fitted with filters. In addition, a 3U fan tray takes up to three equally spaced fans.
SRS Products plc. Tel., 01279 635500; fax, 01279 451220.
Enq no 509

Solderless connectors. Cinch *CIN::APSE* connectors use a new compression method of making and retaining contact which needs no solder, provides a dense array of contacts, is useful into the gigahertz range of frequencies and, having a path length of about 0.8mm, offers a small propagation delay and low inductance of under 1nH. Stacking height is 0.8mm and the connectors are suitable for use in ic array sockets.
Surtech Distribution Ltd. Tel., 01256 840055; fax, 01256 479785
Enq no 503

Polyester enclosures. New enclosures by Briticent are made from a blend of reinforced polyester and glass fibre for use at temperatures between -30°C and 120°C. They are rated to IP65, are resistant to impact and much lighter than equivalent steel types and come in sizes from 300×250×140mm to 800×600×300mm. Doors open through 180°, left or right, on concealed stainless steel hinges. A number of accessories are offered, including a modular chassis; DIN-rail and base plate mounting is provided as standard.
Ensto Briticent International. Tel., 01425 474617; fax, 01425 471595.
Enq no 510

Anti-emi gaskets. Low-profile, beryllium copper gaskets, *ECP 632/636*, have no-snag fingers to eliminate shearing, the size allowing the gaskets to be used where narrow gaps are to be filled with a low closing force. Widths are 11.4mm and 15.2mm, strips are up to 4.06m long and the fingers are 2.54mm wide on a 3.18mm pitch. Attenuation is up to 100dB and mounting is by double-sided adhesive transfer tape.
TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.
Enq no 511

Please quote *"Electronics World"* when seeking further information

Linear integrated circuits

Surface-mounted op-amp. The *NJM2125F* op-amp from the New Japan Radio Company is a single-supply design working from 2.7V to 20V at 1mA. It slews at 1.2V/µs and is contained in an extremely small MTP5 package.
Young-ECC Electronics. Tel., 01628 810727; fax, 01628 810807.
Enq no 512

Logic

"Fastest" 2.5V buffers. Fairchild's VCX group of 2.5V cmos logic devices now includes the *74VCX16827/162827* 20-bit buffers which, in common with the rest of the family, are specified to work on 1.8V, 2.5V and 3.6V supplies; noise and emi generated by elements in this family are less than 0.8V on a 3.3V supply and the *162827* has internal 26Ω resistors to reduce ringing. Both the new devices are in the 56-lead TSSOP package.
Fairchild Semiconductor Corporation. Tel., 01793 856811; fax, 01793 856858; web, www.fairchildsemi.com.
Enq no 513

Wireless cctv. *VideoWave VTX1394* transmitter and *VRX1394* receiver from Low Power Radio Solutions provide secure transmission of CCIR Pal video signals with a range of up to 760m using a 1/4-wave whip; range may be increased to 1km or 2km with more exotic antennas. Several transmitters may be accessed from a single receiver and the transmission is secured by scrambling. Current consumption is 600mA from 12V dc and the units are type approved to MPT1349 for the UK at 1394MHz. Fm channel bandwidth is 10MHz and output power adjustable up to 500mW.
Low Power Radio Solutions Ltd. Tel., 01993 709418; fax, 01993 708575.
Enq no 527

Materials

Thermally conductive insulator. *Kool-Pads K177* and *K228* by Warth are in soft, compliant material providing an alternative to mica washers and grease, the grease not being needed. The material is silicone rubber coated onto a layer of woven glass fibre and will not crack, age or suffer contamination. The pads are available with adhesive or non-adhesive coating and have a thermal resistance of 0.45 or 0.5°C/W, breakdown voltage of 3.5 or 4.5kV and work at temperatures between –60°C and 180°C. Thickness is 0.177mm or 0.228mm.
Warth International Ltd. Tel., 01342 315044; fax, 01342 312969; web, www.warth.co.uk.
Enq no 514

Microprocessors and controllers

8051 with lcd controller. New to the Siemens *C500* family of 8-bit microcontrollers is the *C505L*, said to be the first 8051 to possess a liquid-crystal display controller. The chip is compatible with 80C51/2 controllers and provides 32Kbyte of otp memory, 256Byte of ram, 256byte of xram, an async./sync. serial interface and a 10-bit, 6µs a-to-d converter. Instruction cycle time at 20MHz is 300ns; an integrated clock works in power-down mode, the chip drawing 50µA at 3V in this state.
Siemens plc. Tel., 0990 550500; fax, 01344 396721.
Enq no 515

Mixed-signal ics

Speech synthesiser. Oki's *MSM9831* single-chip synthesiser is claimed to be the smallest available. It uses a non-linear, 8-bit pulse-code modulation algorithm to give equivalent sound quality to that from a 10-bit straight pcm and samples at 4-16kHz. Voice quality and playback time are both selectable, 31 channels providing up to 11s at 4kHz. A serial interface has allowed the use of only eight pins, which makes the device suitable for use in equipment such as cameras and portable CD players. Voltage rail needed is 2-5.5V.
Oki Semiconductor (UK) Ltd. Tel., 01753 516577; fax, 01753 517195.
Enq no 516

Digital pot/comparator chip. Two digitally controlled potentiometers, each driving an analogue voltage comparator, are contained in Xicor's *X9448*, which is expected to find application in voltage threshold measurement and in automatic test. The outcome of the arrangement is that external voltages are compared with the "wiper" voltages, latches setting outputs high or low. Wiper position is determined by registers containing data supplied over a two-wire serial bus.
Xicor Ltd. Tel., 01933 700544; fax, 01933 700533; e-mail, xicor-uk@xicor.com
Enq no 517

Microwave components

Programmable sources. When connected to the parallel port of a 386 or higher pc running Windows 3.1 or higher, *ANS Series* microwave sources from Atlantic Microwave may be programmed to cover a half-octave frequency range in 100kHz steps, software to perform this function being supplied. The source's memory is non-volatile and the units may be used without the pc control, once programmed. Output is +7dBm with –60dBc spurious and –35dBc harmonics, an internal crystal reference maintaining stability at ±2ppm from 0°C to 50°C.
Atlantic Microwave Ltd. Tel., 01376 550220; fax, 01376 552145.
Enq no 518

Optical devices

Optical sensing heads. Two sensing heads by Matsushita are for use with *UZF1/3* amplifiers and are for the detection of glass and silicon in industry. The *UZFRL41* is only 4mm square and has a convergent sensing range of 8mm for transparent objects such as glass boards, only the nearest being detected. *UZFRL42* was designed for use with reflective silicon wafers at 2mm range.
Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599; e-mail, info@macuk.co.uk; web, www.mac-europe.com.
Enq no 519

Oscillators

1 in 10^{11} crystal oscillators. Carrying a claim to be the world's most stable crystal oscillators, the *CPO-1* series from CEPE (now part of C-MAC) stay within ±1 part in 10^{11} over a –20°C to 60°C range, being designed for use as master clocks in SDH/Sonet fixed-line switching and in satellite navigation base stations. Stability can only be matched by atomic clocks at up to twice the price and short-term statistical variance (1-100s at 5MHz) of ±1 in 10^{13} is better than that from an atomic clock. Crystals are SC-cut types with their flattest temperature versus frequency characteristic at the oven temperature. Frequencies available are 2-10MHz or 13MHz for less demanding requirements and, in crystals resonating at 9MHz and above, a special mounting method reduces shock-induced frequency variation. Power consumption from 12, 15 or 24V is 2.4W when steady.
C-MAC Quartz Crystals Ltd. Tel., 01279 626626; fax, 01279 454825.
Enq no 520

Passive components

Power chokes and inductors. API Delevan's *LP Series* of inductors are only 2.4mm in height and are produced in values from 4.7nH to 1µH in tolerances down to ±1%. Operating temperature is –55°C to 90°C. There is also a range of radial-lead chokes for use in switched-mode power supplies. The *3443 Series* covers the range 1µH-15000µH at currents of 0.26A-17.8A; dc resistance 0.005-21.9Ω. A catalogue for both types of device is available.
Mercator. Tel., 01493 334000; fax, 01493 334050.
Enq no 521

Telemetry by pager. *ZACH* is a compact 60 by 60 by 10mm low cost, low power intelligent multi-function control, real time and data pager board. It decodes radio paging POCSAG signals at 512 or 1200bit/s to provide: RS232 data output, on-board relay control, lcd and led activation and messaging, and real time for analogue and digital clocks in 15 time zones. Includes six 'Capcodes,' a versatile sub-addressing scheme, linking together of up to eight paged 250-character messages with encoded and filtered 6, 7 or 8 bit original data. Power 1.2 to 9V dc, 160µA to 30µA. Temperature range 0 to +50 Celsius. Sensitivity 7µV with on-board antenna, 0.7µV with external antenna.
HPM Technologies, 3130 Victoria, Australia, Tel., +61.3. 9877-5033; fax, +61.3.9877-5133, e-mail: hpmtech@hpmtech.com.au.
Enq no 528

Power semiconductors

Tempcomp. audio power Darlingtons. Darlington power transistors in Allegro's *SAP Series* are provided with temperature compensation on the chip to obtain very fast response; idling current is stable in the presence of temperature changes. These are audio power devices in n-p-n or p-n-p form rated at 80W, 100W and 150W and 10A, 12A and 15A
Allegro MicroSystems Inc. Tel., 01932 253355; fax, 01932 246622; web, www.allegromicro.com
Enq no 522

Protection devices

Resettable fuses. *PolySwitch RGE* is a range of Raychem resettable fuses which now includes several new devices, current coverage now being 3A to 14A to replace larger, slower, higher-resistance devices at higher currents. Trip times are, for example, 5s at 10A for the 4A type and 40s at 30A in the 14A fuse. The fuses are around one-third the size of older types, the 4A version being 8.9mm 11.9mm.
Raychem Ltd. Tel., 0800 968626 (free); fax, 0800 968627; web, www.Raychem.com.
Enq no 523

Please quote *"Electronics World"* when seeking further information

Switches and relays

Miniature signal relay. *Model G5V-1* sealed signal relay by Omron is an extremely small device for communications and general switching use. It takes up less than 1 cubic centimetre and uses 150mW, the spdt contacts handling 1-2mA at up to 125Vac/60Vdc. Impulse withstand voltage is 1.5kV in accordance with FCC part 68.
Onboard Electronics Ltd. Tel., 01256 818222; fax, 01256 840610; e-mail, onboardelectronics@compuserve.com
Enq no 524

Transducers and sensors

Pressure transducer. *Model 210-90-050-XX* is a miniature, flush-mounted transducer by Paine Corporation that is only 32mm long and which is meant for use where frequent flushing or cleaning is needed or when the medium is a thick slurry. Output is 1mV/V and temperature rating 135°C. Amplified types are also available to give 0-5V output for pressures of 0-500lb/in^2 to 0-10000lb/in^2.
Endevco UK Ltd. Tel., 01763 261311; fax, 01763 261120; e-mail, sales@endevco.co.uk.
Enq no 525

Telemetry receiver. A synthesised receiver module by Wood & Douglas is crystal-controlled and frequency-selectable by a serial interface. The board-mounted, nickel-silver *SR500* module stores frequencies in non-volatile memory and an optional parallel interface permits the selection of eight programmed channels. *SR500* is ETSI and MPT approved and is available now in the 430-470MHz band; versions for the 130-185MHz and 860-880MHz bands will follow. Switching bandwidth is 8MHz, channel spacing 12.5, 20 or 25kHz, channel switching time under 50ms and the outputs are analogue or digital.
Wood and Douglas Ltd. Tel., 0118 981 1444; fax, 0118 981 1567; e-mail, info@woodanddougls.co.uk; web, www.woodanddouglas.co.uk.
Enq no 531

Wafer thermostat. Now available in the UK, the *Airpax Series 5003* thermostat is a sealed, wafer-type thermal switch measuring a mere 0.25in deep and weighing 2.3g. It is a bimetallic type with a positive, reinforced snap action with rapid thermal response. Ratings are 3A and 240V ac and operating temperature may be set between 1.6°C and 163°C with narrow or standard switching differentials. The thermostats are UL recognised and CSA certified.
EAO Ltd. Tel., 01444 236000; fax, 01444 236641; e-mail uksales@eao.com; web, www.eao-group.com
Enq no 526

EQUIPMENT

Power supplies

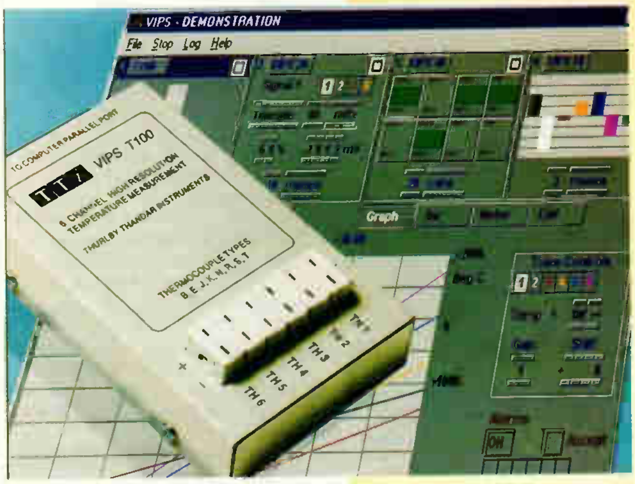
Dual-output dc-dc converter. 30W dual-output converters in the Calex *CS Series* are designed for use in 5V logic systems with disk storage, the 5/12V outputs handling 5V microprocessors and driving hard disks or CD-roms; the 12V output is rated for 4A surge for rapid startup of large drives. Input range is 9-36V for the *24D5.12CS* and 20-72V for the *48D5.12CS* models, the 5V output being rated at 3A and the 12V output at 1.3A, with load regulation, cross and line regulation and noise 120mVpk-pk. There is short-circuit protection by current limit and thermal shutdown. An output trim facility provides ±10% variation.
Calex Electronics Ltd. Tel., 01525 373178; fax, 01525 851319; e-mail, calex@btinternet.com; web, www.calex.co.uk.
Enq no 529

Production test equipment

Screen-printing inspection. DEK Printing Machines offers *DEK 2Di*, a set of inspection tools to monitor screen printing processes. It is built into the printing machine and looks for stencil blockage and smearing on the bottom of the stencil, tests for paste on the pad, and paste alignment with the pad, and bridging between pads. Each inspection site is of 4mm x 4mm and there may be over 200 sites per board. Depending on the error level, the machine may stop or give a warning or, in closed-loop control, will start the stencil-cleaning cycle. As the company points out, it is better to get it right before printing than to find bad print later.
Dek Printing MachinesLtd. Tel., 01305 760760; fax, 01305 760123; web, www.dek.com.
Enq no 530

Radio systems

Am transmitter. RF Solutions' miniature am transmitter is meant for security, car alarms and data-capture use at fixed frequencies of 315, 418 or 433MHz, sending data at up to 4kHz at a range of 70m. It accepts data from a microcontroller, encoder or any cmos/ttl source with no need for extra circuitry. Current needed is 4mA from a 2-14V supply and the device measures 18 × 11mm in sil or dil form. The company's range of receivers will work with this transmitter.
RF Solutions Ltd. Tel., 01273 488880; fax, 01273 480661; e-mail icepic@pavilion.co.uk; web, www.rfsolutions.co.uk.
Enq no 532



Test and measurement

Video inspection. Standard specification of Cambridge Technology's complete video inspection system includes a 1-50× zoom lens, a high-resolution camera, an A6 video/digital printer, a precision stand and colour monitor, options being a 50/500× zoom lens and digital image archiving.
Cambridge Technology Systems. Tel., 01223 892020; fax, 01223 894385.
Enq no 533

Signal-conditioning for recorder. Signal conditioning for voltage, current, pulse and strain-gauge inputs is provided by a range of modules for Yokogawa's *DR230*, a fast, multi-channel data-acquisition and recording instrument. The modules expand the instrument's capacity to 300 channels for inputs up to 500m away, one of the modules being a dedicated ac power type, calculating power, frequency, power factor and kWh from ac voltage and current input. A further module conditions inputs from thermocouples and resistive temperature detectors. Records are printed on 250mm wide charts in analogue and digital form and may be saved on an internal floppy disk Computer interfaces are provided as options.
Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002; e-mail, info@martron.co.uk; web www.martron.co.uk
Enq no 535

Temperature module. Newest in the range of virtual instrument pods from TTi is the *VIPS-T100* 16-bit-resolution temperature measurement module for thermocouples, operating from a pc's parallel port, which also provides the power. Six connectors take thermocouples of types B, E, J, K, N, R, S or T, different types being mixed on the same unit; the inputs may also be used to measure voltage down to 1μV. Four units may be used together to give up to 24 channels. Windows software provides display and control, the display showing the data in the form of meters, graphs, charts and listings, the inputs being scaled and offset for each channel and channel names provided. Dll drivers are available.
Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.
Enq no 534

I/Q modulation generator. Modulation generator *AMIQ* and its associated *WinIQSIM* software constitute a response to the need for test equipment in the presence of an increased use of I/Q modulation in communications. AMIQ is a dual-channel instrument, designed as a 100MHz I/Q source with a 4Msample memory and 14-bit amplitude resolution – a performance required for the generation of signals for digital systems such as wide-band code-division multiplex access (w-cdma). An automatic amplitude/offset alignment process greatly reduces error vector, which has previously been very difficult to achieve. When combined with the software, the equipment provides, for example, up to 512 multi-carrier signals, cdma signals with selectable coded channels and a data editor to create any tdma frame configuration.
Rohde & Schwarz UK Ltd. Tel., 01252 811377; fax, 01252 811447; web, www.rsd.de./UK.
Enq no 536

£300, 20MHz oscilloscope. For less than £300, Feedback offers the

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CS-4125 20MHz, dual-channel oscilloscope, which is principally intended for use in education. It is particularly simple in operation and the instrument meets all relevant safety standards. Sensitivity is 1mV/division to 5V/division and the –3dB bandwidth 20MHz at sensitivities over 2mV/div. (5MHz below). Fastest sweep at ×10 expansion is 20ns/div.The 150mm tube has an internal graticule and its accelerating voltage is 2kV.
*Feedback Test and Measurement. Tel., 01892 653322; fax, 01892 663719; e-mail, feedback@fdbk.demon.co.uk; web, www.fbk.com***Enq no 537**

COMPUTER AND DATA HANDLING

Computers

Multimedia single-board computer. Graphics, video and audio are all within the range of Blue Chip's *Pentium PC* has up to 64Mb of dram, 512Kb L2 cache memory and, for diskless operation, the option of plug-in flash from 2Mb to 72Mb and up to 512Kb of sram. The board uses Pentium processors to P200MMX and the PCI Local bus svga video and its 1Mb of memory drives 3.3V and 5V 24-bit tft and dstn lcds. It has four serial ports, dual USB ports a parallel port and PCI-based Ethernet controller, in addition to hard and floppy drives.
Blue Chip Technology. Tel., 01829 772000; fax, 01829 772001; e-mail, sales@bluechiptechnology.co.uk; web, www.bluechiptechnology.co.uk.
Enq no 538

PCMCIA line transformers. APC has a group of very thin ISDN S line transformers for mounting on PCMCIA cards. The height of the transformers is 2.54mm and they take up one side of the board, leaving the other free for circuitry. First available are *APC48201/2/3*, all of which contain dual S transformers for transmit and receive in one 24 × 14.88 × 2.54mm package. Turns ratios available are 1:1, 1:2 and 1:2.5.
Advanced Power Components Ltd. Tel., 01634 290588; fax, 01634 290591; web, www.apcisdn.com.
Enq no 551

Computer board-level products

68040 cpu. *BVME4500* by BVM is a VMEbus module using a 33MHz 68040 processor and, having much in common with the rest of BVM's processor family, allows portable applications between them. It comes in a 3U form and is also made in an extended-temperature version. A choice of memory is offered, all dual-ported to the bus. There is 2Mbyte of 32-bit-wide non-volatile sram and 2Mbyte of 32-bit boot-sector flash eprom. Two extra modules expand memory to 16Mbyte of flash and 96Mbyte of dram. Boot-sector flash may be remotely programmed from the bus. Two RS232 ports and a 32-bit dma-driven, 10BaseT Ethernet port are on-board with connections on the front panel.
BVM Ltd., Tel., 01489 780144; fax. 01489 783 589; email, sales@bvmltd.co.uk; web,www.bvmltd.co.uk.
Enq no 539

Data acquisition

***Odyssey* acquisition card.** Nicolet has introduced an additional card for the Odyssey data-acquisition mainframe. *OD-200* combines the functions of transient recorder, data-logger and oscilloscope, using 10Msample/s digitisers for transient recording and so achieving 100 times the transient capture speed of the original card, the OD-100. There are four channels, each with a 14-bit, 10Msample/s a-to-d converter, trigger circuitry and 5MHz filtered differential amplifiers. As a transient recorder, the card will stream data at up to 1Msample/s to a 4Gbyte or 9Gbyte hard disk, additionally providing XY and fast Fourier, as well as ordinary X/t displays .
Nicolet Technologies Ltd. Tel., 01908 225630; fax, 01908 225633; e-mail, Nicolet_Technologies_Ltd@msn.com
Enq no 540

Data communications

Single-chip bert. Vitesse's *VSC8109* contains all necessary bit error rate tester functions in the one ic. It is for use in 2.5Gb/s and 10Gb/s Sonet/SDH test systems, generating and comparing 16-bit 155/622Mb/s pseudorandom binary sequences. Used with multiplexers and demultiplexers, the device makes a simple serial tester, also providing serial test in wavelength division multiplex systems. Sequence lengths with up to 2^{31} permutations are supported and the comparator has a 16-bit error accumulator with overflow.
Broadband Technology 2000Ltd. Tel., 01494 474800; fax, 01494 443100; e-mail, 100616.3040@compuserve.com.
Enq no 541

Interfaces

GPIB meets FireWire. National Instruments has a new interface that connects computers equipped with an IEEE1394 'FireWire' port to GPIB instruments. With the *GPIB-1394*, up to 14 programmable GPIB-based engineering or scientific instruments can be integrated with computers equipped with an IEEE1394 interface quickly and easily. The *1394* is compatible with industry-standard instrumentation software such as LabVIEW, LabWindows/CVI, and ComponentWorks for Visual Basic.
National Instruments. Tel., 01635 523545; fax, (01635) 523154, e-mail: info.uk@natinst.com.
Enq no 542

Mass storage

Combined rewritable optical and CD-rom drive. Panasonic's *LF-1097* SCSI-2-compatible drive is a combined 650Mbyte PD rewritable optical disc drive and 24× CD-rom drive that gives better performance than rewritable CD-roms but will still play CDs, the one drive serving both purposes. Seagate's *Backup Exec* software is supplied with the drive, which is also compatible with the company's DVD-ram drives and with dos 6.0. Windows 3.1, 95 and NT 3.51, OS/2 Warp 3.0 and higher, and for Unix with Sun Solaris, and SCO Openserver.
Panasonic. Tel., 0800 444220.
Enq no 543

Software

Displaying physical changes in workpieces. *DIAdem-Insight* by GfS mbH of Aachen is a new feature of the DIAdem data acquisition, analysis and graphics software that displays changes in a test item by means of animation. For example, it will show as colour changes or as physical displacements the effects of heat, vibration resonances or loading on a structure or machine during a measurement, the display being saved for further use or for transmission elsewhere. The cursor may be scrolled through the measurement data to indicate the exact occurrence of an event.
Strategic Test and Measurement Systems Ltd. Tel., 01203 323160; fax, 01203 323161; e-mail,info@strategic-test.com; web, www.strategic-test.com
Enq no 544

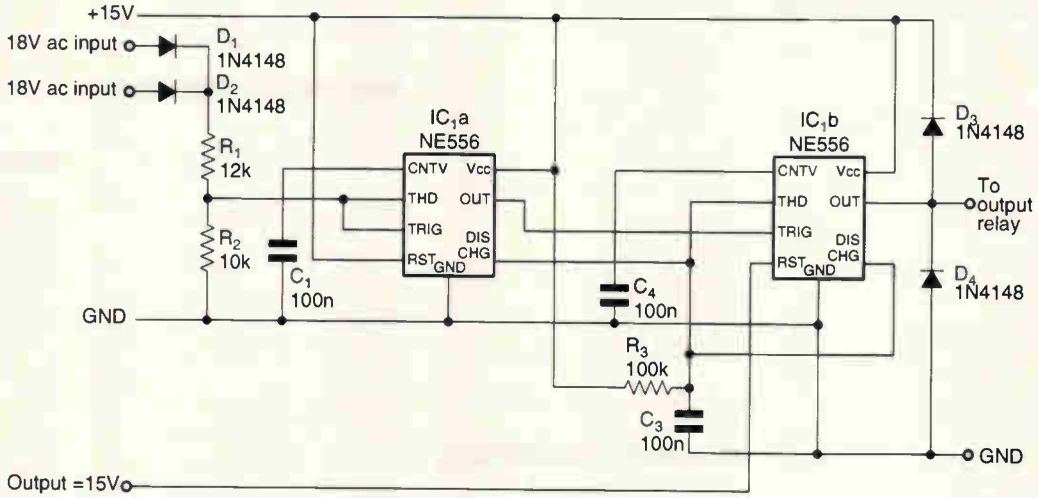
Pcb design. Accel announces three developments to its printed-board design software. *Signal Integrity*, which was developed with Incases GmbH, provides accurate simulation of reflection and crosstalk effects on pcb layouts and is intended mainly for use in the design of digital circuitry working at 20MHz and above or low-voltage circuitry vulnerable to noise. *Accel Gerber* by Advanced CAM Technologies, assists in the translation of designs to the manufacturing stage, while *Dr Spice* and *Dr Spice 2000* are for the simulation of analogue and mixed-signal design, the free library containing more than 20000 parts.
Britcomp Sales Ltd. Tel., 01372 362111; fax, 01372 362333; e-mail sales@britcomp.com
Enq no 545

Field strength calculation. Version 3.02 of Wandel & Goltermanns' *EFC-400* simulation software for 0-500Hz electric and magnetic fields now has automated display management. Clicking the mouse will produce printed forms for documenting and display and a dialogue box assists in navigating the system. The software simulates hv overhead lines, buried cables, substations, etc., and a data archive supplies pylons and other power lines to the simulation, after which actual background field strengths and various frequencies from different sources can be taken into account.
Wandel & Goltermann GmbH. Tel., 0049 7121 8616 16; fax, 0049 7121 8613 33; e-mail, info@wago.de; web, www.wg.com
Enq no 546

Flotherm v.2 for Windows NT. *Flotherm v.2*, Flomerics' thermal analysis software is now available for use with Windows NT. This facility simulates air flow and heat dissipated by components and systems to assist in the identification and solution of overheating problems. New in version 2 are a new graphical interface that presents a cad-like appearance; three windows to provide an overall view, geometry creation and 3-D graphics, the windows being interactive; thermal models of common parts such as fans and heat sinks; a radiation model; and interpretation and simplification of imports from other software.
Flomerics Ltd. Tel., 0181 941 8810; fax, 0181 9418730; e-mail flomerics@flomerics.co.uk; web, www.flomerics.com.
Enq no 547

Mathcad extended. Extension packs and electronic books are introduced by Mathsoft to provide extra functions for *Mathcad 7. Mathcad 7* extensions include one containing numerical recipes for differential equations, optimisation and data modelling, based on the Cambridge University Press book Numerical Recipes in C by Press *et al.* For image processing, there is a pack to assist in smoothing, crisping, edge detection, erosion and dilation on colour and greyscale images and, for signal processing, there is a pack to provide over 60 functions in acoustic, optical, digital or analogue operations. The electronic reference books are on electrical engineering (Hicks), mechanical engineering (Roark) and civil engineering (also Roark).
Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213; e-mail, info@adeptscience.co.uk; web, www.adeptscience.co.uk.
Enq no 548 ■

Holding off application of power to a muting relay during the switching on and off of an audio amplifier avoids noisy – and sometimes expensive – transients.



(B67)

Muting an audio amplifier during power switching

To avoid clicks, bangs and possible speaker troubles when switching the power to an audio amplifier, it is advisable to reduce the resulting transients or to isolate them; this circuit isolates them by means of a relay in a muting circuit, as used in the design by R. Williamson (*EW*, December 1995).

The *NE556* dual timer's left-hand half is used to convert the rectified and voltage-divided ac input to a rectangular wave, its output triggering the other half, which is a monostable to drive the relay.

Each time the squarer emits a trigger, it also discharges the timing capacitor of the monostable, C_3, the output going high and activating the relay after the power supply has had time to reach its operating levels.

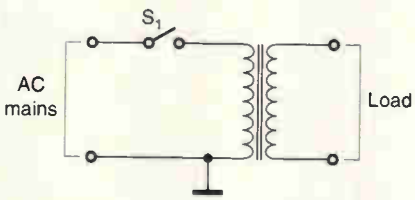
At switch-off, the ac is removed before the supply rail capacitors discharge. Ac disappears and C_3 charges up completely, so that the output goes low and the relay is de-activated. The relay is therefore always turned off during the application or removal of the ac supply.

To ensure that the relay is not switched on at the same time as the amplifier, a 15V signal obtained from a schmitt trigger in the power supply holds the monostable off until the supply is established.

Bernard Van den Abeele
Evergem
Belgium
B67

Ac spike suppressor

(B57)



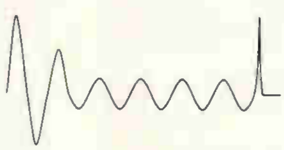


Fig. 1. Switching on a transformer causes spikes due to leakage inductance and inter-winding capacitance.

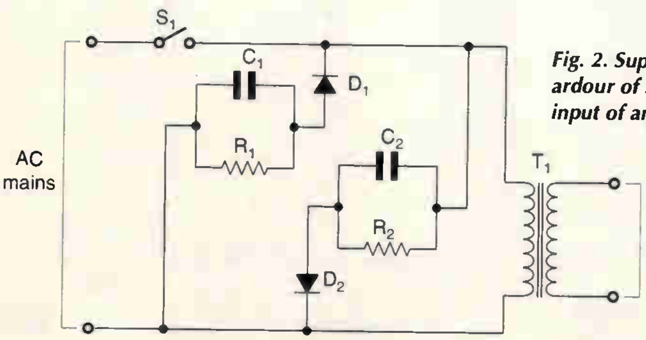


Fig. 2. Suppressor circuit dampens the ardour of spikes caused by switching the input of an isolation transformer.

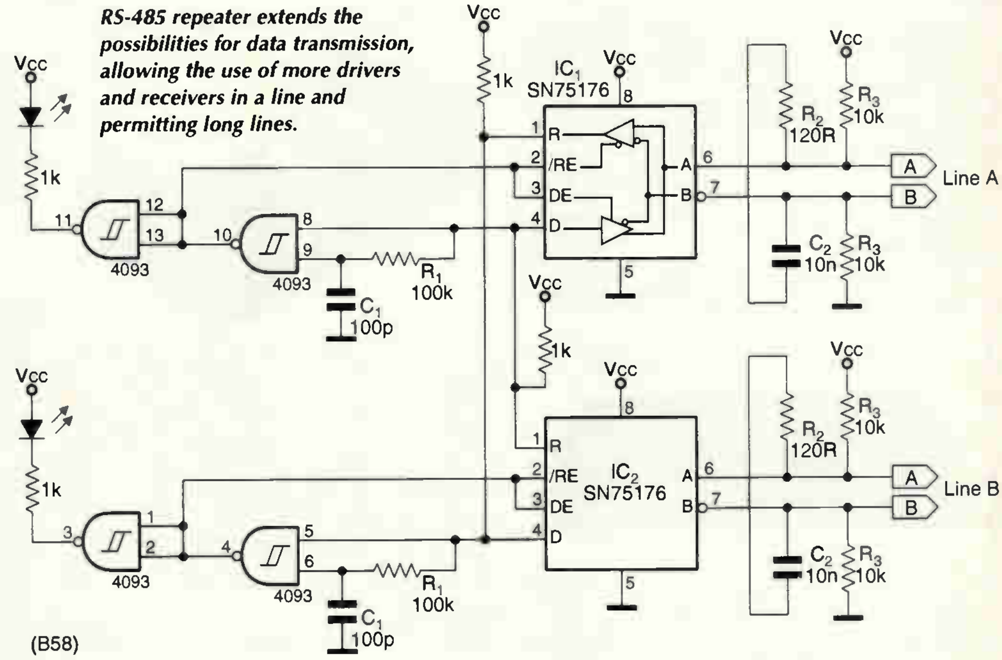
Switching power to a circuit on the primary side of an isolation transformer has a tendency to cause switching spikes, due to the existence of leakage inductance and inter-winding capacitance. **Figure 1** shows the familiar gruesome result. The arrangement of **Fig. 2** stops all that, as shown in the waveform diagram.

Depending in which half-cycle of the mains waveform the power is switched, $D_{1/2}$ conducts and $C_{1/2}$ absorbs the extra energy, discharging through the resistor. Diodes are fast-acting types and must be able to handle peak current for a short time. Select component values to take account of leakage inductance, winding capacitance and load.

Vijayan Pillai
Npol
Kochi Kerala
India
B57

Bidirectional RS-485 repeater

RS-485 repeater extends the possibilities for data transmission, allowing the use of more drivers and receivers in a line and permitting long lines.



(B58)

To be inserted in long lines or to allow radial lines in a star arrangement to be isolated from the others, each being terminated, this repeater shows which line is receiving data and opens the other line to forward the data.

A line not transmitting is inactive , its state being logic one. Both drivers are disabled and both receivers enabled. If no driver is active in the line, resistors R_3 keep it at one.

If line A goes to zero, the receiver in IC_1 detects the level. Output pin R is taken to IC_2 input pin D, IC_2 being activated at pin DE by gate IC_2 and imposing a zero on line B. Reception on line B is disabled at pin /RE. This state of affairs lasts while the zero level remains on Line A.

When line A goes to one again, line B is driven to one and is disabled after a time R_1C_1, overriding the effect of the resistors R_3. The time constant of terminating components R_2C_2 should be shorter than that of R_1C_1 to allow C_2 to charge by the driver before the driver is disabled. Nevertheless, R_1C_1 has to be shorter than the time of one bit.

The circuit has operated at 9600baud and should go to 100kbaud.

Albert Pijuan
Girona
Catalonia
Spain
B58

Split supply from a single battery

From the one battery, this circuit arrangement produces symmetrical positive and negative outputs equal to the battery voltage and is protected against short circuits

The 741 op-amp operates as a 1kHz square-wave generator and is, at switch-on, supplied with $V_{batt}/2$ to each supply pin by way of the two diodes. When the op-amp starts to oscillate, its output drives the transistors, their outputs being superimposed on the battery voltage and the op-amp now receiving double its steady-state supply.

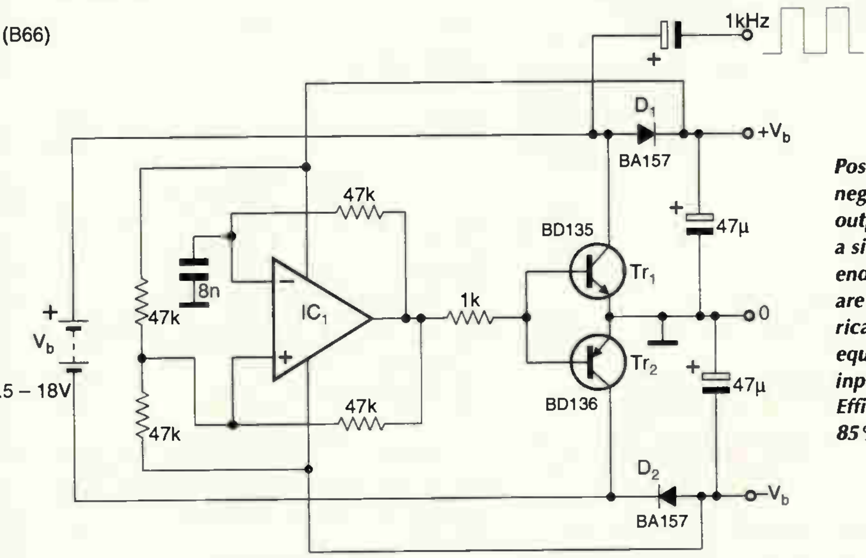
The increased voltages are taken as the output after smoothing by the two 47μF capacitors. If required, the square wave is available as an output and, if symmetry of the square wave needs adjustment, the 47kΩ resistors on the op-amp input can be replaced by a potentiometer.

In the event of an excessive demand from the load, the oscillator stops and output current is reduced.

Efficiency is about 85% with a 12V supply and the maximum operating frequency is about 20kHz; above that, faster diodes will be needed. Higher powers could be achieved with low on-resistance mosfets and Schottky diodes.

Edward Reszke
Wroclaw
Poland
B66

(B66)



Positive and negative outputs from a single-ended supply are symmetrical and equal to the input. Efficiency is 85%.

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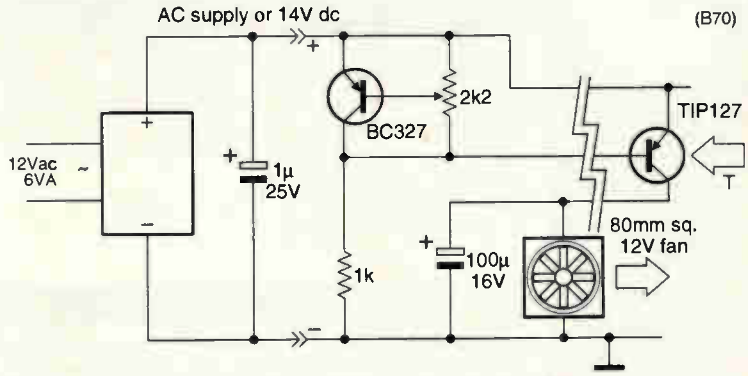
G S Maynard
Newtownabbey
Co. Antrim
Northern Ireland
B70



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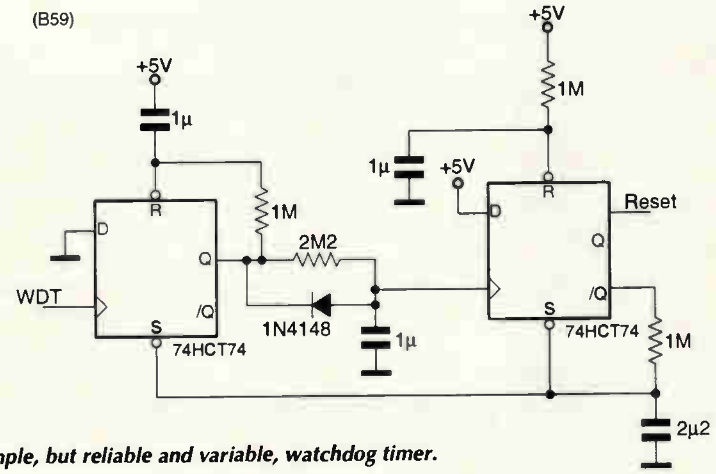
Cristóbal Rueda Guerrero
Malaga
Spain
B59



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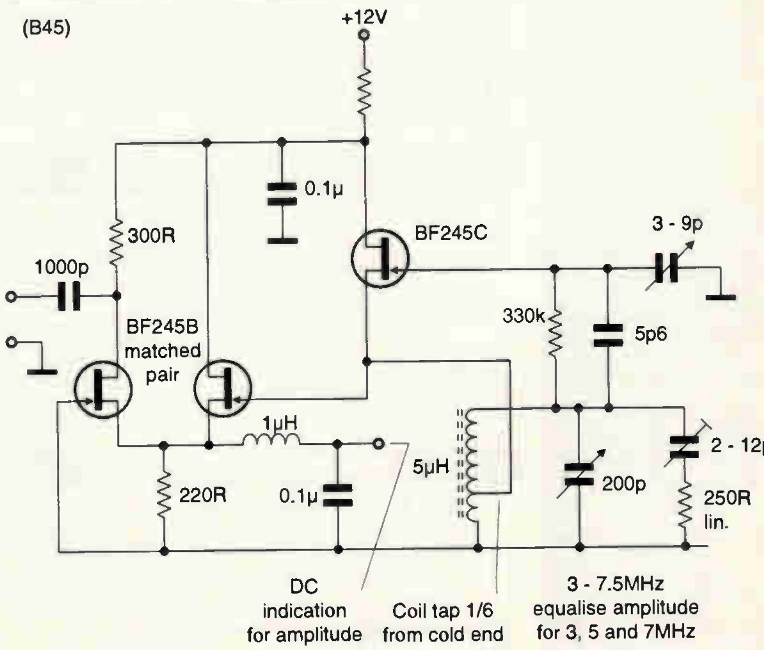
Wim de Ruyter
Oudkarspel
Netherlands
B45



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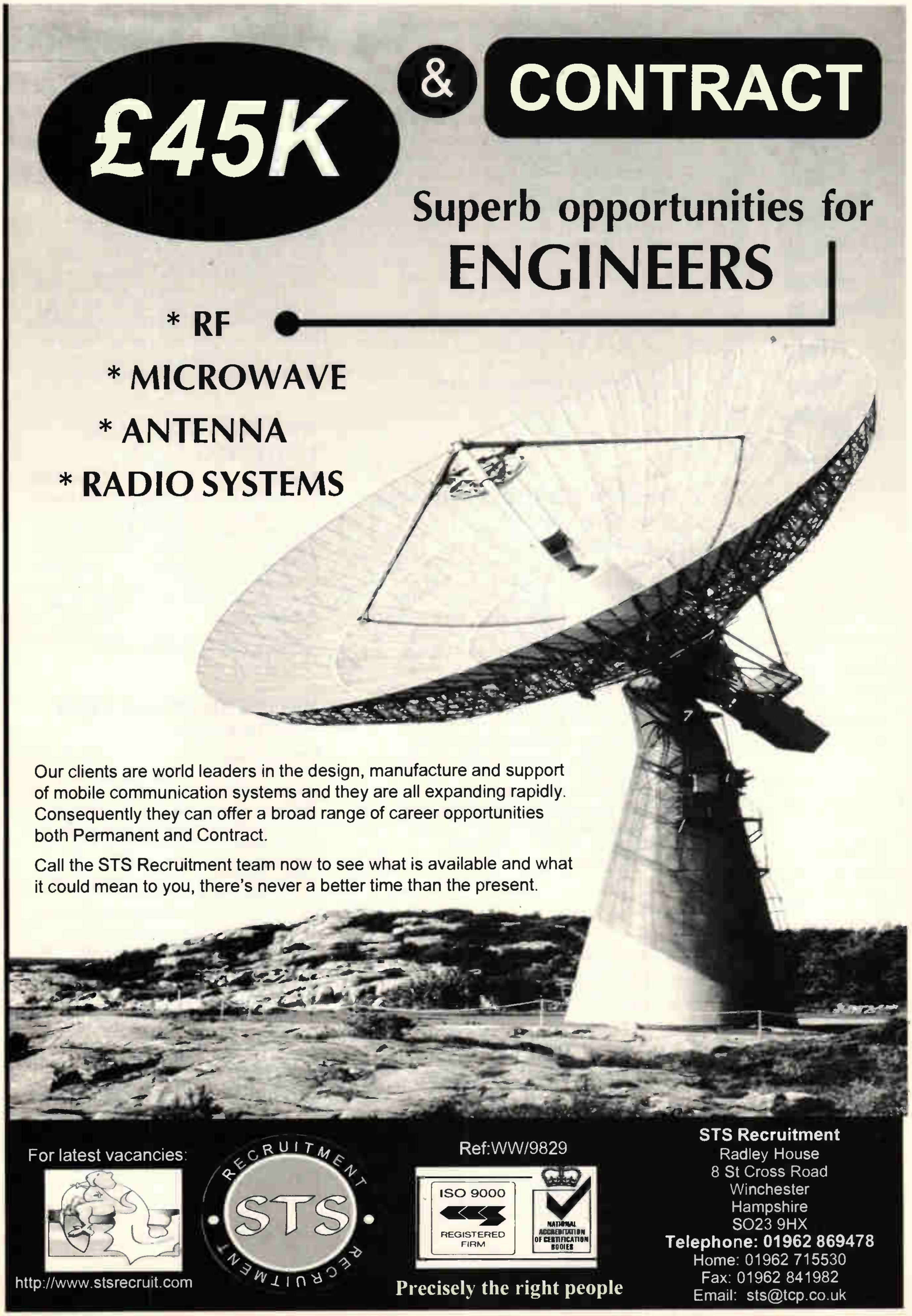
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* RADIO SYSTEMS
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Call the STS Recruitment team now to see what is available and what it could mean to you, there's never a better time than the present.
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SOFTWARE ● HARDWARE

TALENTED DESIGNERS!

Electro-mech
Various locations £20-£40k

Are you a talented Designer with a background in mechanical design? Are you currently in a job which you feel is taking you nowhere? Or are you just interested in finding out a bit more about what opportunities there are out there for you? In either case we would like to hear from you. We have lots of high quality client companies who are looking for good, creative Designers – using ProEngineer, SDRC, Autocad, Catia, Unigraphics and others! Opportunities genuinely exist in a number of market areas including telecomms, audio, power supply, automotive, aerospace. Don't wait any longer – make the decision to further your career today!

RF DESIGN ENGINEERS

Wiltshire £20k to £40k

This highly successful company has placed its GSM centre of excellence in the UK and is investing not only in the technology but also in highly skilled technical engineers. You will be responsible for the design and development of various RF products including Synthesisers, Receivers, Transmitters and control loops for the next generation of base station equipment. You should have experience of simulation using HP EEsof with previous experience of designing RF products within the communications.

RF DESIGN ENGINEER

Hants/Surrey £22k to £37k

Degree qualified engineers with 2-8 years relevant RF circuit design experience are required to work for this world leader in the design and development of GSM, PCN and Satellite communications products. You should have a high level of experience in designing Receivers, Synthesisers LNA's and Transmitters up to 2 GHz and have experience in designing products for high volume manufacturing. You should also be willing to work at the bench testing designs.

RF DESIGN ENGINEER

Herts/Cambs £Exceptional

This superb company is looking for several highly experienced RF Design Engineers who have extensive experience of RF Design and Development in the HF and VHF (50 to 200 MHz) spectrum. You should have solid experience in the design of low cost Rx/Tx, LNA's, Mixers, VCO's Synthesisers, PA's and Filters taking the relevant ETSI standards into consideration. Any experience of UHF would be highly beneficial.

YOUNG RF DESIGN ENGINEER

Wilts to £30k + bonuses

This household name, with a diverse product range, requires a talented young RF Design Engineer at their UK design centre working on designs for a variety of mobile communication applications. You will be a practical 'hands on' engineer with experience of LNAs, transmitters and receivers together with RF modelling tools. Working under pressure to tight timescales you should be capable of working on your own initiative, whilst supporting other team members.

RF DESIGN ENGINEERS

Cambs, M3 & M4 £Superb

The current Telecommunications market is providing excellent opportunities for RF Design Engineers at all levels. Due to the demand for experienced design engineers we currently have over twenty positions covering various technologies and of course locations. In short the requirements are for RF Design Engineers with hands-on experience of Receivers, Transmitters, Synthesisers, LNA's and Filters. Frequency ranges are typical of the telecoms market usually to 2GHz. Technology areas of interest are CDMA, GSM and PCN in either a mobile phones or base stations. Other relevant product areas include modern design and digital radio. You should be well versed in CAD/CAE tools such as HP EESof, Touchstone and PSPICE to name a few. Salary levels on offer depend on experience gained but for engineers with 1-3 years £25-£30k and 3 years + £30-45k.

RF DESIGN ENGINEERS

Herts/Cambs £18k to 45k

Very well respected company involved in the design and development of many of today's high tech communications products is looking to recruit RF Engineers who have an excellent track record in the design of innovative Radio/Mobile communications products. You will need a good degree coupled with solid experience of GSM, PMR, CDMA, RF design including Amplifiers, Mixers, Synthesisers to 1.8 GHz. You should also have good experience of simulation packages such as HP EEsof or Touchstone.

IC DESIGNERS

Hants to £40k

This newly established group offers this opportunity to work in a small organisation environment and yet be part of a large international company which has been a highly respected household name for many years. They now seek several talented IC design engineers at various levels of seniority. The main skills areas they wish to recruit in are RF IC design and digital CMOS IC design. Experience of high level design tools will be required and any mobile comms or broadcast experience will be useful. This company is looking to recruit individuals who wish to further their skills and be highly rewarded for their efforts ensuring that they have the status they deserve.

RF CIRCUIT/IC DESIGN/APPLICATIONS

UK/USA £Excellent

As a recognised leader within the world of RF components this client offers an excellent opportunity to become part of a team of design engineers within a commercial organisation. You will be designing/supporting products for a variety of RF application, but primarily mobile communications. You will need at least 2 years experience of RF design at board or IC level. You will have the opportunity to work in the UK (Berkshire) or the USA (California). Excellent salaries are available for successful candidates. Contact Steve Davis.

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APPOINTMENTS

BBC

BBC Research and Development

Kingswood Warren, Tadworth, Surrey.

Research and Development Department provides engineering R&D for the BBC. Working with partners in the UK and Europe, we are currently undertaking projects in all areas of broadcasting including digital television, digital radio and multimedia projects. To contribute to our progress in these areas, we seek two highly creative individuals who are ready to take their knowledge and skills to new levels.

Spectrum Planning Group is a team of about thirty professional engineers who handle all matters relating to the provision of radio spectrum to new services, protection of existing services, effects on non-broadcast services, national and international co-ordination, and providing outline designs for new transmitters.

Research & Development Engineer

Salary in the range: £22,000 - £28,000 according to experience.

You will be contributing to the successful launch of the BBC's terrestrial digital television and digital radio services, carrying out research, software development and practical measurements to refine and update the planning processes, an area which has increased greatly with the move into new OFDM-based digital transmission systems.

Holding a good honours degree in Electronics, Physics, Computer Sciences or a closely related subject, you should have broadcast engineering experience, preferably in an R&D capacity. An effective communicator who can lead and motivate support staff, you'll be a good team player and be ready to make a significant contribution to our continuing success.

Initially the work is in Spectrum Planning Group, but in the future you may be required to work in any of the other groups in the Department: Studio, Multimedia & Networking, Transmission Systems and System Design.
Ref. 28878/AS

Service Planning Engineer

Salary in the range: £17,500 - £23,000 according to experience.

The work will involve site tests for proposed new transmitting stations and surveys of the coverage of existing ones, as well as work at Kingswood, calibrating and setting up equipment in vehicles.

You must be qualified to Higher National Certificate, Higher TEC or equivalent standard in the field of Electronic/Electrical Engineering, Physics or Computer Sciences, have good knowledge of radio-frequency measurement techniques and possess a valid UK driving licence. You should have experience of using a personal computer and a basic understanding of radio propagation.

You will receive training in the use of survey vehicles and equipment, including our helicopter-borne transmitter survey system, and you will then be required to work individually or as part of a small team. Although based at Kingswood Warren, you must be prepared to travel and work for periods anywhere in the UK, and this may include weekend working. **Ref. 28879/AS**

We are located in attractive surroundings in Kingswood, Surrey, with staff restaurant and club facilities. Further information on BBC Research & Development and our work can be obtained from our web site at **http:/www.bbc.co.uk/rd**

For further details and an application form, please contact BBC Recruitment Services (quoting appropriate ref.) by September 21st on 0181-740 0005, Minicom 0181-225 9878. Alternatively, send a postcard to BBC Recruitment Services, PO Box 7000, London W12 8GJ, or e-mail recserv@bbc.co.uk quoting ref. and giving your full name and address. Application forms to be returned by September 24th.

You can also see this vacancy on http://www.bbc.co.uk/jobs/e28878.shtml and apply online from our world wide web site.

BBC

Working for equality of opportunity