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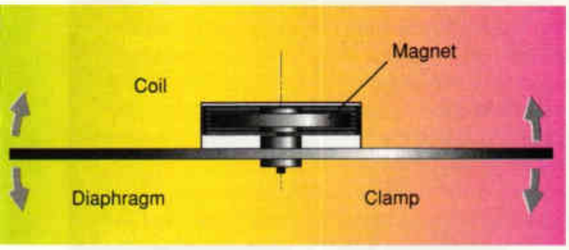

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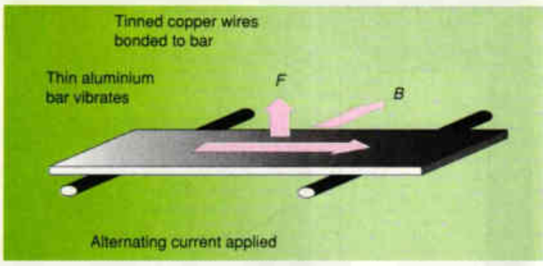

Special offer

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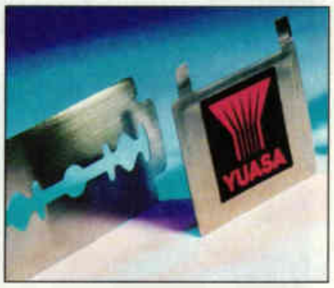

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REED BUSINESS PUBLISHING

Where do we go from here?

Electronics gives a real problem to those who would edit magazines on the subject. There was a time when one designer could reasonably determine every aspect of major significance about the project which he was working on. He might have shared the design responsibilities with other people simply because doing the whole lot himself would have been hopelessly inefficient.

Take an airport radar set of the early seventies. One can be fairly certain that the bloke who designed the plumbing at the rf front end could have developed the rest of the exciter and logarithmic receiver chain just as easily. He – it was almost certainly a he – might have needed to bone up on the delay-line signal processing which effected the anti-clutter circuitry. Should we use the tried and tested acoustic delay lines, large oil filled tubes with analogue transducers at opposite ends, or go for a digital delay using those new fangled a-to-d converters and ttl shift registers? He was able to hack it either way. We all were.

The rest of the video and control circuitry was a doddle. Power supplies? No problem. Everything used big transformers with thyristor phase control surrounded by analogue circuitry. The aerial array itself? A specialised design art. It always was and always will be. But even here, there was no mystery. A parabola dish uses the physics of an 'O' level light bench. A planar phased array? The principle was simple enough. If you math-modelled each element as a right-angled triangle, feed phase angle replacing one of the sides, you could make the array squint anywhere with nothing more complicated than schoolboy trigonometry.

It was easy to edit *Wireless World* in those days. We could usefully cover every circuit and system design aspect knowing that the resultant article would interest a sizeable proportion of the readership. It is not so easy today.

Take the example of the personal mobile phone. We can report and write about the rf front end circuit blocks since these interest a reasonable number of people. However, one could probably count the readers equipped to handle and integrate these devices into something useful on one hand - unless of course you are writing specifically for the design departments of the phone makers. This we don't need to do because the chip companies feed these people directly with everything they need.

Portable phones make extensive use of dsp to

shape IF passbands, keep watch on channel occupancy, tailor audio response and handle signal compression. Great stuff this, but you have to be a mathematician first and a designer second to get anywhere near the bottom of it.

The situation here is further complicated by the development tools needed to make any of the chip systems do anything useful. You must be serious – and rich – to purchase these things. This denies use of such techniques to almost everyone except corporate r&d departments.

But in spite of this, everyone here promises to make these important things as approachable as possible for the largest number of people.

Then there is the technological cliche of our times, the microprocessor.

The devices and systems which get used in our exemplary portable phones are actually microcontrollers. Phone operation depends on handfuls of them. We mostly know about micros yet a magazine devoted to their programming – because that is the essence of the subject – would be dry indeed and have little to do with 'electronics'. The development tools are cheap though.

Taken together, that piece of high technology in your pocket represents the reality of electronics today. Yet its design process will only be of interest to a few people. So what do you want to read in *Electronics World*?

Our letters columns have always been the spirit of the magazine and its forbears. Keep that spirit going by telling us what you would like to see in our pages. We hope you need our views. We certainly need yours. Please keep writing so that we can keep writing. ■

Frank Ogden

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Development funds dilemma for key future technologies

A Parliamentary body is arguing that the UK could miss out on developing a key technology of the next century through lack of funding.

According to the Parliamentary Office of Science and Technology (POST), the recent DTI Technology Foresight programme does not highlight the importance of nanotechnology. "The Foresight process was remarkable for its lack of mention of the subject," says a report by POST.

Dr Michael Norton, director of POST, said: "It is important whether your technology is seen as a priority by the Technology Foresight programme." This is because funding from awards schemes, such as the Foresight Challenge, depends heavily on the programme. The report agrees that "current research priorities centre on the recommendations of the 1995 Technology Foresight programme". Norton noted that all the relevant centres of excellence in nanotechnology have failed to obtain funding from the Foresight awards.

However, Prof Steven Beaumont, who convenes the Nanoelectronics Research Centre's management committee at Glasgow University, disputes whether there is a funding problem. "The UK's current position in funding for nanotechnology is reasonably good," he said, adding that significant investments were being made in the area.

The problem, according to Beaumont, lies in the definition of nanotechnology. "Some people would say that nanotechnology is just sectors like polymer science and molecular electronics with a different label," he said. "Others, who wish to promote nanotechnology as being new, would say something different."

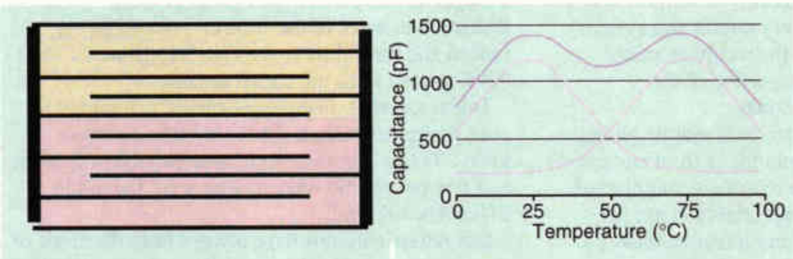
But it is research into nanotechnology as a generic technology, rather than into specific applications, that is important, according to the POST report. "Recent exercises in the USA," it says, "focused directly on identifying 'critical technologies' and concluded that nanotechnology is clearly one of those 'generic technologies' underpinning a wide range of technologies and markets."

Jon Mainwaring,
Electronics Weekly

Five times more capacitance from multi-layer relaxor devices

In the new capacitor, two relaxor dielectrics – normally unusable because of their poor thermal performance – work together to produce an acceptable temperature curve and very high capacitance/volume ratio.

Oxley Developments has demonstrated a multi-layer ceramic capacitor type with "up to five times greater capacitance per unit volume than at present". Oxley does not make individual capacitors but incorporates capacitive structures into connectors, filters and feed-through devices.



Spokesman Steve North said: "Capacitor makers are going to be pretty excited when they hear about this."

The new capacitor exploits 'relaxor' dielectrics. These materials have some of the highest known dielectric constants but are normally rendered unusable by their appaling temperature characteristics.

In conjunction with Dr Andrew Tavernor of the University of Leeds, Oxley has developed a composite structure which effectively combines two relaxor dielectric-based capacitors in parallel. The materials have different temperature responses and compensate for one another, stabilising the capacitance over a wide temperature range.

Oxley has shown that the new device can achieve an X7R temperature characteristic with a dielectric constant of 15,000, giving a volume four times smaller than the current best X7R materials. Capacitors made using the process, called Ceramox UHK, are entering an 18-month period of aging and accelerated lifetime testing.

Price policing on Internet

All that flat-priced Internet access may soon be a pleasant memory as Internet watchers begin to tout pricing models that will offer users several tiers of service, with different guaranteed levels of data transport.

This is seen as one way to limit traffic on the Internet, preventing system overload.

Researchers at the University of Texas in Austin say that they have developed some pricing models which appear to work well.

And others have proposed methods that would allow each packet of Internet data to bid for services. In this way, when the network is congested, those willing to pay more will gain access.

If you'd like to keep up with all the latest surveys about Internet usage and when the Internet is supposed to collapse under a digital tsunami, you can access this survey's own Internet site. It will also keep you informed by e-mail about any surveys that come out. The address is: http://www.nua.ie/choice/surveys/

Global Mondex on cards

The global acceptance of Mondex's electronic purse is on the cards if MasterCard acquires a majority stake in Mondex, formed by the NatWest and Midland Banks and backed by BT. MasterCard is talking to Mondex about taking a controlling 51% stake.

"MasterCard has had discussions with Mondex but, as MasterCard researches and develops ways to shape the future of money, we will continue to seek potential partnerships that will better position us to do this," said a MasterCard spokesman.

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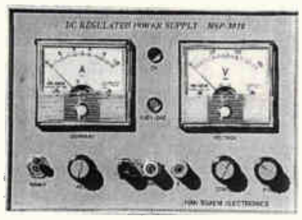

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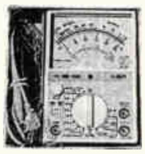

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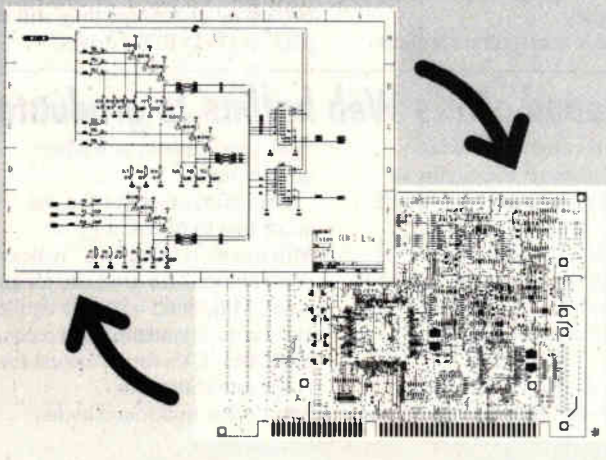

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CIRCLE NO. 109 ON REPLY CARD

New cathode-ray tube technology "beats flat screens"

Toshiba has demonstrated its latest crt technology for mixed tv and computer display use, and has stressed that crts still give the best pictures when compared with flat-panel displays.

Toshiba crt spokesman Masayuki Nakanishi said: "The speed of liquid-crystal-based displays is just not good enough for fast moving images. This can be seen when portable pcs are used to display video. Flat-panel displays have, of course, much less volume, but are five times more expensive for a given size."

The innovations in Toshiba's tubes revolve around reducing power consumption and/or increasing brightness.

Traditional colour crts use a grey-tinted front plate to increase contrast by absorbing ambient light reflected from the phosphor dots – which are actually off-white in colour.

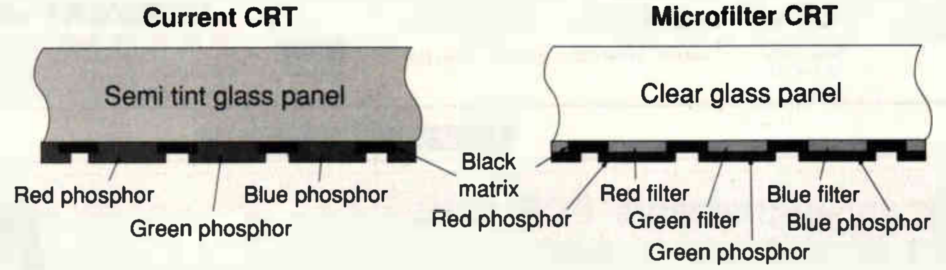
The company has introduced Microfilter, which is an array of colour-matched filters, one for each phosphor dot. These absorb all ambient light that is not the same colour as the emissive colour of the dot. The overall effect is a dramatic reduction in phosphor reflections, allowing a clear front plate to be used. This, in turn, increases the amount of phosphor output that the viewer sees. Either 30% more brightness or a power reduction of 25% is claimed using Microfilter.

In a separate development, Toshiba has reduced the neck (electron gun housing) diameter from 29mm to 22.5mm. This puts the scanning magnetics nearer the electron beams, allowing less power to be used for beam deflection. The disadvantage is that focusing is more difficult, thus requiring the development of a better focusing system.

This, however, has been achieved, with the spin-off that the company has a gun for its bigger 29mm-necked range of tubes which has better resolution that its forebears. This makes the tubes better able to display computer information in multimedia applications.

"Reducing power consumption does not only benefit the environment. Low power tubes reduce the cost of power supply components and air conditioning requirements," said Nakanishi.

***Steve Bush**, Electronics Weekly*



Toshiba's Microfilter array reduces phosphor reflections and enables the use of a clear glass front plate.

Silicon Valley safe as monopoly law fails

California's high-tech companies declared victory in an expensive, hard-fought contest to defeat a proposed new law that would make it easier for lawyers to file class action shareholder lawsuits – the bane of Silicon Valley firms.

Proposition 211 was resoundingly defeated by California voters last month, but the two sides spent almost $80m arguing their respective positions in a blitz of television, radio and newspaper advertisements – making it the most expensive campaign in California's history.

Some firms, notably Intel and Advanced Micro Devices, had refused to talk to financial analysts in the weeks before the vote, saying that they did not want to leave themselves open to lawsuits had Proposition 211 been passed.

Immediately following the election results being announced, Intel issued a forward-looking statement saying that strong demand for PCs was leading to record sales. Intel said it expects its fourth-quarter revenue to be significantly higher than its third quarter's $5.14bn.

"Assuming continued strength in billings, the company expects gross margin percentage in the fourth quarter to be above the third quarter's level of 57%," Intel said.

Fujitsu plans first PC with built-in DVD-ROM

Fujitsu says it will be the first to introduce a pc with a built-in DVD-ROM drive, giving users access to almost 5Gbyte of data stored on optical media. The model will be part of its *FMV Deskpower* family and initially will be available only in Japan.

Other pc manufacturers around the world have plans for similar DVD-equipped pcs and, by the end of next year, the first recordable DVD drives should be available.

DVD drives are predicted to replace cd-rom counterparts in coming years. CD-roms store only 600Mbyte of data but they will still play on DVD-ROM drives.

Milkround offers Web hotline to graduates

Electronics employers who complain about the quality of modern graduates could do worse than take a look at Milkround Online. This is a Web-based recruitment service which acts as a cheap recruitment option for firms wanting to attract top-quality graduates.

Leaflets promoting Milkround have been sent to thousands of final-year students at leading universities.

The main reason for the site, according to Nick Gregg of Milkround, is that it is a "reasonable cost solution" for graduate recruitment. Milkround will give employers access to students' and recent graduates' CVs for an annual fee.

The site address is: http://www.milkround.co.uk/

Modem manufacturers in race to set new 56kbit/s standard

Battle lines are being drawn in the contest to define the standard for the next generation of 56kbit/s (56k) modem technology.

Ascend Communications intends to work with Rockwell Semiconductor Systems to deliver 56k modem connections by January next year. Ascend has the support of 300 Internet service providers (ISPs).

Ascend's planned use of Rockwell's 56k modem chipset, with its Max Wan switches, will allow ISPs and other online providers to offer 56k connections as long as users employ Rockwell-based modems.

The move challenges US Robotics, whose own 56k modem technology has also won the support of major ISPs and online service providers such as IBM, Prodigy and AOL.

The standards battle could delay the establishment of an industry standard by as much as two years, as the two firms line up supporters.

"Ascend plans to be the first remote-access vendor to actually deliver on the promise of 56kbit/s technology," said Mory Ejabat, Ascend's president and CEO. "We believe this technology opens the door for a new generation of high-performance Internet and remote-access applications, so our goal is to provide the most robust implementation and the earliest deployment."

US Robotics, however, says it will be able to upgrade millions of its modem users through software, and leverage its position as the market-leading supplier of modems to set a *de facto* industry standard.

Meanwhile, Lucent Technologies last week announced its own 56k modem chipset, available in volume early next year, with commercial modems available by mid-year.

Tom Foremski, *Electronics Weekly*

Speedier production line programming

The industry's use of very large programmable devices has prompted Stag Programmers to adopt an embedded 32-bit PowerPC 403GA, custom Asics, and a 57kbyte/s download interface for its latest production programmer.

Elgan Howell, MD of Stag, said: "Current technology programmers take around eight minutes to programme a 16Mbit flash part. This is a long time on a production line."

The theoretical programming time for this size of memory is far shorter, but the processing required to implement appropriate programming algorithms adds a disproportionate delay to the process. The addition of a 24Mips processor has allowed Stag to reduce programming time to 64s.

It has also moved to IEEE1284 instead of the traditional RS-232 interface for data transfer between the user's data repository and the programmer. Howell said: "Waiting half an hour for a file to download to a programmer is becoming unacceptable. The new interface is five times faster than the RS-232."

The Stag programmer is the first result of its 18-month ground-up range redesign. Called the P803, it is an eight-gang machine dedicated for use with memories and microcontrollers.

The unit is supplied with pc control software for remote control and file management. Its own software is held in flash and can be reprogrammed with new algorithms by users on-site.

Steve Bush, *Electronics Weekly*

Tracking toy tempts showgoers

Visitors to two US satellite shows were impressed by a model truck used by UK firm Signal Processors to demonstrate its INTRAC antenna control system.

This produced a beam of light that maintained its orientation toward a distant model satellite despite the truck being moved around.

Signal Processors chief executive Dr Robin Smith-Saville said: "We could have sold the truck a dozen times over." The Cambridge-based company is a satellite communication subsystem specialist.

Its products include satellite modems, for which it claims to be the largest European manufacturer, data broadcast receivers, and satellite antenna controllers.

WindRiver makes code clearer

WindRiver, the US embedded tool company, has introduced a structure viewing tool allowing the relationship between objects in object-oriented code to be identified and displayed in a GUI format.

Called *WindNavigator*, the tool can be used to view Java, C, C++ and Tcl. "A picture is worth a thousand words. When there are 20 engineers working on a project, it is almost impossible for any one person to determine the overall code structure," said Steve Harris, UK general manager for WindRiver.

"Even if it has been designed in a strictly top-down process, there is a distinct possibility that some designers will be less disciplined than others. WindNavigator allows a clear picture of the code to be viewed."

Although it is not the only tool of its kind, Harris claims it is the only one that can cope with more than one million lines of code.

Intel and TI in move to abolish key indicator

A clash over the future of the semiconductor book-to-bill (BB) ratio has broken out between the USA and the rest of the world.

In the USA, Intel and Texas Instruments are trying to persuade the industry's trade body, the Semiconductor Industry Association (SIA), the drop the BB because the ratio has a detrimental effect on stock market prices when it is declining.

However, the president of World Semiconductor Trade Statistics (WSTS), Jean Philippe Dauvin, thinks that this would be a mistake. "The BB is 25 years old and is an indicator which works," he said. "For the last ten months it's been going down but now it's at 1:1 and it's going to go up, so it's crazy to kill it off now, when it's going to help stock prices."

The BB ratio is published eight days after the end of each month, but the WSTS Blue Book, giving statistics from which the BB can be calculated, comes out 20 days after the end of the month. So abolishing the BB will not affect the financial community's judgment on stock prices, Dauvin believes.

The SIA BB relates only to US manufacturers. WSTS publishes a worldwide BB. ■

RESEARCH NOTES

Jonathan Campbell

Computers put on a funny face

Work is currently being carried out all over the world into the field of interactive computer agents – animated characters, with 'personalities' who will one day become the 'face' of our computers.

The latest idea coming out of MIT's Media Lab on this front is Gandalf – a character capable of face-to-face interaction with people in real-time, and able to perceive their gestures, speech, and gaze. Except he can't do all that just yet, but the project does show how control of a graphical face could produce some of the behaviour exhibited by people in conversation. The eventual aim is to enable people to interact with computers in the same manner they interact with other humans.

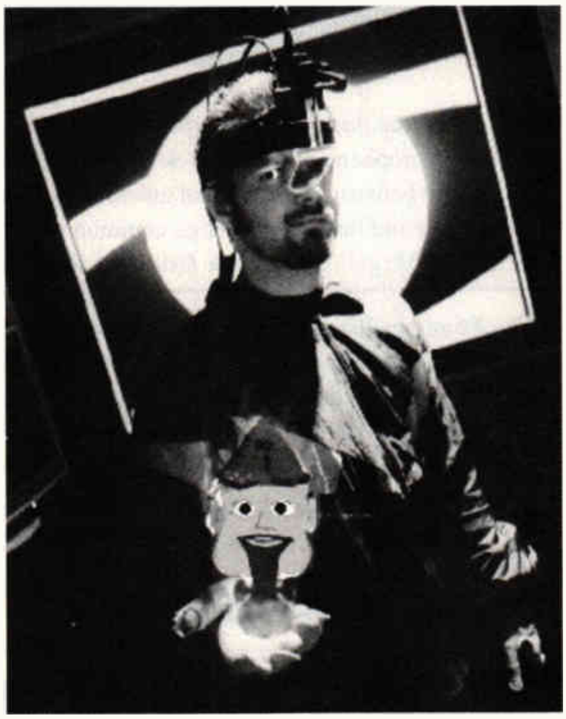
Gandalf was developed by MIT graduate Kristinn Thórisson working with Professor Justine Cassell, head of the MIT Media Lab's Gesture and Narrative Language group. "When we look closely at how people communicate," says Cassell, "we find them using not only the spoken word, but also intonation, pauses, and facial and body gestures. If computers could understand these non-verbal communications, they could adapt to us, instead of making us adapt to them."

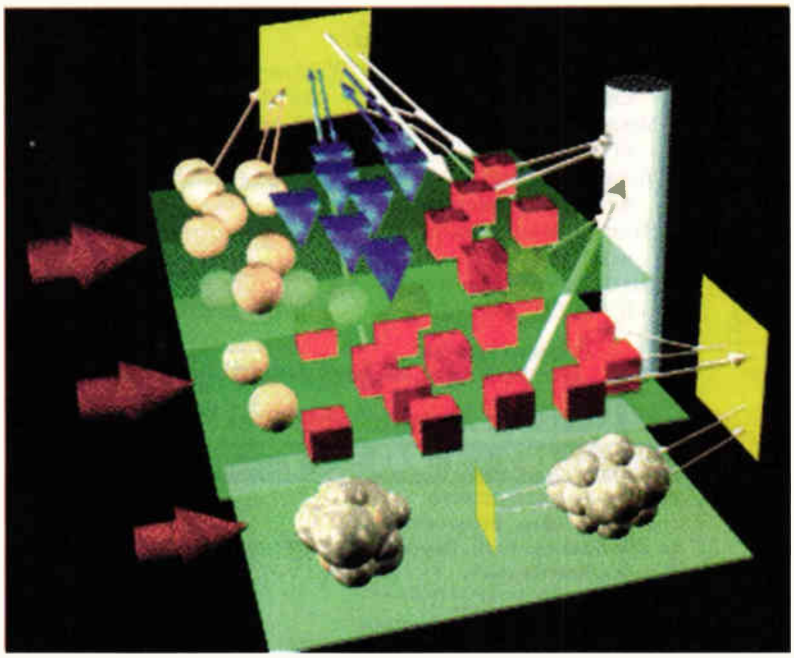
Currently, to interact with Gandalf the user must wear a body-tracking suit, an eye tracker, and a microphone. But eventually this equipment will become unnecessary as computer-vision systems become able to perceive the user's visual and auditory behaviour.

Communicating with Gandalf can be a bit of a palaver at the moment. But as computer-vision systems develop, the extra hardware should become unnecessary.

Thórisson explains that Gandalf is based on creation of an architecture for psychosocial dialogue skills that allows implementation of 'full-duplex' multimodal characters so that they accept multimodal input and generate multimodal output in real-time, and are interruptable.

The architecture is based on three AI approaches: Blackboards, Schema Theory and Behaviour-based AI.





Inside Gandalf's head? How the MIT agent responds

Multimodal information streams in from the user (see picture, big arrows on left) and is processed at three different levels, using blackboards (yellow planes) for communicating intermediate and final results. An action scheduler (cylinder) composes particular motor commands and sends them to the agent's animation module.

Part of the work includes generating interactive facial animation in a cartoon-style approach. For this Thórisson is developing a ToonFace system, based on an object-oriented approach to graphical faces which he says easily allows for rapid construction of whacky-looking characters – automatically.

The animation scheme allows a controlling system to address a single feature on the face, or any combination of features, and animate them smoothly from one position to the next.

"This is not morphing," says Thórisson. "Any conceivable configuration of any movable facial feature can be achieved instantly without having to add 'examples' into a constantly expanding database. The system employs the notion of 'motors' that operate on the facial features and move them in either one or two dimensions".

Gandalf can currently answer questions about the planets of the solar system. But future work includes adding more complex natural language understanding and generation, and an increased ability to follow dialogue in real time.

Contact: Professor Justine Cassell, MIT Media Lab, Cambridge, MA 02139-4307, USA.

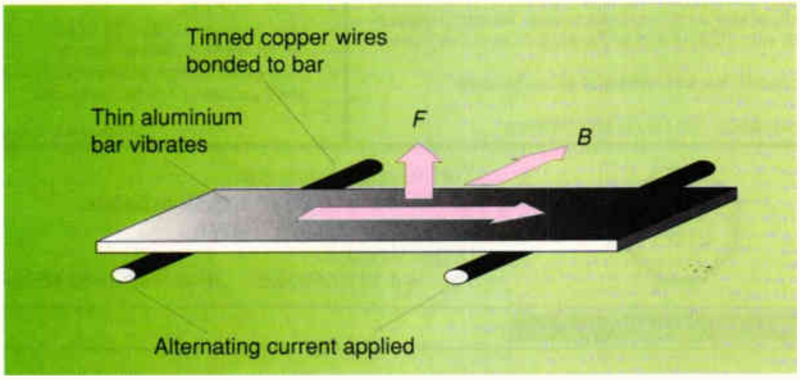
Miniature magnetometer hits the right note

Xylophone magnetometer combines high sensitivity with linear response.

Innovative design by researchers in the Applied Physics Laboratory of the Johns Hopkins University has produced a high sensitivity magnetometer based on a xylophone resonator. Test data from the prototype device shows it to be intrinsically linear, and by altering the drive current, the sensitivity can range form nanoteslas to teslas.

The work is valuable because of the increasing interest being shown in development of miniature magnetometers for mapping magnetic fields in space and in industrial and environmental applications. The trend is constantly toward smaller size, lower power consumption – and lower cost for similar performance.

Approaches to the problem in the past have included piezoresistive and magnetorestrictive cantilever designs, and magnetometers based on electron tunnelling effects. But such devices have been limited to measuring in the range mT to µT.



The Johns Hopkins prototype magnetometer ('A high sensitivity, wide dynamic range magnetometer designed on a xylophone resonator,' RB Givens *et al*, *Appl Phys Lett*, Vol 69, No 18, pp. 2754-2757) consists of a thin aluminium bar, 39 by 2.43 by 0.9mm in dimensions. This is supported by two 18mm long strands of 3 by 0.08mm diameter tinned copper wires, positioned at the nodal points that would be expected for a bar free at both ends and vibrating in its fundamental node. The wires are bonded to the bar to provide low resistance electrical contacts.

In operation, rms currents up to 1A, generated by a sinusoidal source oscillating at the fundamental transverse resonant mode, are applied to the bar.

The Lorentz force generated by the current and the applied magnetic field causes the xylophone to vibrate in its fundamental mode, with the amplitude being proportional to the vector component of the field in the plane of the bar and parallel to the support wires. This amplitude can then be measured using the deflection of a dc-driven laser beam reflected from one of the free ends of the bar onto a position-sensitive detector.

One of the likely future advantages of the design is that its principle of operation lends itself to miniaturisation. So more work is to be carried out to investigate reducing the dimensions of the device so that it can be produced – including its integral supports – using photolithography or microelectromechanical processing. The researchers are also examining the possibility of fabricating arrays of sensors to allow for high sensitivity magnetic imaging.

Contact: R B Givens, Applied Physics Laboratory, The Johns Hopkins University, Laurel, Maryland 20723-6099, USA, or email D K Wickenden at wickenden@jhuapl.edu

Linear induction motor handles beautifully

Handling and moving work around a manufacturing plant is one of the most underestimated burdens on business, across industry. So the promise by three US researchers to increase material transfer speeds by a factor of ten through the use of a linear induction motor (lim) could hold widespread promise.

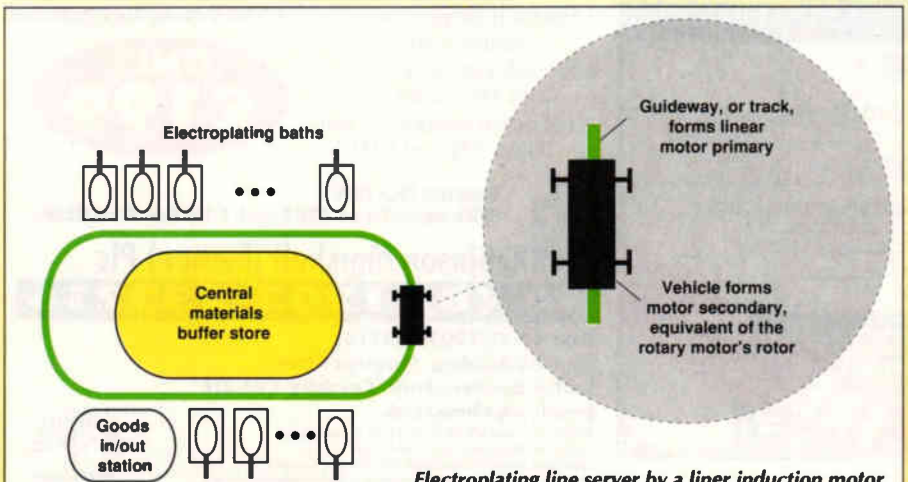
The basis of the high-speed transfer line is a continuous, closed loop transfer system using a high-speed, direct-drive lim.

Technology behind the lim is now well established. In concept, it is a rotary motor cut and laid flat. The thrust in the lim is produced when power applied to the primary winding, the guideway, induces a flux into the secondary windings to propel the secondary winding, the vehicle. What Ramakrishna Desiraju and colleagues have done ('Performance analysis of a new electroplating line configuration with a linear induction motor based material mover', *IEEE Trans on Robotics and Automation*, vol 12, No 4, pp. 590-595), is to use the unique acceleration rates and stability of a lim material mover to design a much simpler handling system. The high speeds make transportation times so much shorter that processing equipment can be located further apart, and further from the retrieval and storage systems without compromising performance. Speed of the vehicle also means that only one material mover is needed on the system and so complex scheduling and logic to avoid congestion can be avoided.

The researchers' prototype lim vehicle, built at the University of Wisconsin-Madison, accelerates up to 4g and can travel at the speeds of 60-120km/h, compared to 1-8km/h for conventional material handling systems. System design also makes use of the lim's short turning radius, its high cornering speed, the ability to offer a modifiable network topology and low maintenance.

So far the work has been based on a system that could be used to serve an electroplating line. But the team says that the principles could equally apply to other types of flexible manufacturing systems.

H M Wang, Industrial Engineering, University of Wisconsin, WI 53706 USA



Electroplating line server by a liner induction motor vehicle could cut handling times by factor of ten

Cool news on measuring hot spots

Radiation detectors, operating at room temperature but achieving levels of performance approaching that of liquid-nitrogen-cooled detectors, have become a practical proposition following work carried out at the Ernest Orlando Lawrence Berkeley National Laboratory in California. The detectors also have a directional capability and could form the basis for imaging systems.

Paul Luke, a staff scientist in Berkeley Lab's Engineering Division, has developed a method that eliminates the need for cooling, so enabling smaller, more portable and less expensive detector systems to be produced. The development is expected to open up a whole set of uses, where good energy resolution is desired but liquid-nitrogen cooling is not practical – for example hand-held instruments.

Applications are expected to include medical diagnostics, nuclear safeguards, nuclear physics, balloon- or space-based gamma-ray astrophysics, environmental monitoring and industrial sensing.

Detectors conventionally work by sensing the ionisation produced by radiation. Commonly, the detector configuration consists of a volume of detecting medium – solid, liquid or gas – sandwiched by two plane electrodes to which a voltage is applied. Incoming radiation strikes the detecting medium, loosening positive and negative electric charges which travel to the electrodes and register a charge signal.

Several materials can be used as the detecting medium but, except for germanium and silicon, the charge collection process is far from perfect. Often, the positive charges are not as efficiently collected as the negative ones, resulting in an inaccurate reading of the ionisation, so that the signal's strength can not be relied upon to indicate energy of the radiation.

The improved detector uses an arrangement of parallel strip electrodes, and a technique called 'charge subtraction' to provide a much more accurate reading of the energy of radiation. The parallel strips are interconnected to form two sets of interdigital electrodes. Charge signals induced on these two electrodes are subtracted to yield a net signal that is insensitive to charge trapping. As a result, energy resolution is greatly improved.

Importantly, the technique can be applied to wide band-gap compound semiconductors, such as cadmium telluride, cadmium zinc telluride and mercuric iodide – materials that offer advantages over silicon and germanium, the main one being that their wider band-gaps allows them to be operated at room temperature.

Researchers have been attempting to use compound semiconductors in radiation detectors for the past twenty years. But because of poor charge collection in these materials, the detector performance was not satisfactory for many applications. The new technique largely overcomes this problem and could allow the detectors to detect radiation such as X rays and gamma rays with energy resolution close to that of silicon and germanium detectors.

A second unique feature of the invention is its use of induced charge signals to determine the depth of radiation interaction in the detector. By measuring the difference between the total charge induced by a particle of radiation and the charge induced at one of the two grid electrodes, it is possible to determine where the ionisation originates along the direction perpendicular to the electrode planes.

This can be used, in conjunction with shadow masks or X-ray optics, to determine the direction of incoming radiation, thus providing imaging capability.

Berkeley Lab's Patent Department has already licensed the invention to one company, and they are having talks with several other prospective licensees.

The crying game

You've fed it, burped it, changed its nappy and its still crying. So what is that baby trying to tell you? Researchers in the Speech Recognition and Language Understanding Services Laboratory in the US and at the University of British Columbia in Canada may have the answer, because they have developed a system that can interpret a baby's cry – automatically.

It has long been an attractive proposition to be able to monitor and analyse baby's cries remotely (though babies looking around for a comforting human being might not agree). Now, Qiaobing Xie and and his colleagues look to have laid the groundwork for design of an automatic cry analysis system that can do just that.

The system has been built by integrating large amounts of data concerning knowledge of infant cries with modern signal analysis techniques. The cry recordings were first transferred onto two-track audio cassettes and then digitised with a sampling rate of 8kHz after being low-pass filtered at 4kHz. A resolution of 12 bits was used for the digitisation.

The team was then able to break the cries down into a series of different cry modes, characterised by particular types of time-frequency patterns on spectrograms. By analysing the sequences of modes, the researchers say they can assess the level of distress of the baby.

So far, the results seem to back them up. Testing with a number of different cries, uttered by infants under various degrees of stimulation, has shown that the system can arrive at assessments of the distress levels of infants, consistent with the perceptions of parents.

On this basis, the researchers say they believe it is now possible to develop practical applications for automatic infant cry analysis. Such systems could assist physicians in the diagnosis of certain infant diseases by analysing cry signals and detecting disease-related patterns in a clinical environment.

However, if any entrepreneurial manufacturer could package the system up in pink and blue, with a rabbit on the front, there's quite a few sleep-deprived parents who would snap it up too. ■

Load-invariant audio power

Loudspeaker impedance can vary widely over the audio spectrum and as the impedance rises and falls, the power amplifier linearity changes. But it need not, as Doug Self's latest design illustrates.

My investigations into power amplifiers have so far largely concentrated on 8Ω resistive loading. This is open to criticism, as loudspeaker impedance dips to 4Ω or less are not uncommon. Solid-state amplifiers always give more distortion with heavier loading, without exception so far as I am aware.

While it would be highly desirable from the amplifier designer's point of view for the loudspeaker designer to strive for a reasonably flat impedance, it has to be accepted that electronic problems are much easier to solve than electromechanical ones. It follows that it is reasonable for amplifiers to accommodate themselves to loudspeakers rather than the other way around. Thus an amplifier must be able to cope gracefully with impedance dips to 4Ω or lower.

Such dips tend to be localised in frequency, so music does not often dwell in them. An amplifier should be capable of driving half the nominal load impedance at almost the full voltage swing, though not necessarily for more than a minute or so.

Contemporary power amplifier ratings tend to be presented in the format '*X* watts into 8Ω, *Y* watts into 4Ω' from which we presumably may deduce:

- The amplifier will deliver sustained power into 4Ω.

- Since 2Ω loads are not explicitly mentioned, they cannot be driven in a sustained fashion.

It may also be assumed, but with much less certainty, that,

- The amplifier will cope with short-term 2Ω impedance dips; ie half the lowest nominal load quoted.

- The overload protection – if it exists at all – activates below 2Ω. Note that no minimum load impedance is specified.

Table 1. Characteristics of distortion mechanisms.

No.	Mechanism	Category	Component sensitive?
1	Input V_{in}/I_{out} nonlinearity	Inherent	No
2	VAS I_{in}/V_{out} nonlinearity	Inherent	Yes?
3	Output stage distortions:		
	a) Large-signal nonlinearity	Inherent	Yes
	b) Crossover distortion	Inherent	No?
	c) Switch-off distortion	Inherent	Yes
4	Non-linear voltage-amplifier stage loading	Inherent	Yes
5	Rail decouple grounding	Topological	No
6	Rail current induction	Topological	No
7	Error in negative-feedback take-off-point	Topological	No
8	Feedback cap distortion.	Inherent	Yes

Output loading and distortion

A 'Blameless' Class-B power amplifier is one wherein all the distortion mechanisms shown in **Table 1** have been eliminated or reduced to below the noise floor, except for the intractable Distortion 3 in its three sub-categories. I have produced a slim monograph which describes the philosophy and practicalities of this in greater detail than *EW* articles permit.[1]

A Blameless design gives a distortion performance into 8Ω that depends very little on variable transistor characteristics such as beta. This is because at this load impedance the output stage nonlinearity is almost all crossover distortion, which is primarily a voltage-domain effect.

Note that for optimal crossover behaviour the quantity to be set is V_q, the voltage across the two output emitter resistors R_e, and the actual value of the resulting I_q is incidental.[2] Mercifully, in Class-B the same V_q remains optimal whatever the load impedance; if it did not the extra complications would be serious.

As the load impedance of a Blameless Class-B amplifier is decreased from infinite to 4Ω, distortion increases in an intriguing manner. Unloaded, the thd is not much greater than that from the Audio Precision test oscillator, but with loading crossover distortion increases steadily, **Fig. 1**.

When the load impedance falls below about 8Ω, a new distortion begins to appear, overlaid on the existing crossover nonlinearities. It is low-order, and essentially third-harmonic. In **Fig. 2** the upper 4Ω thd trace is consistently twice that for 8Ω, once it clears the noise floor.

In part 5 of my series Distortion In Power Amplifiers in the December 1993 issue, I labelled this as Distortion 3a, or large signal nonlinearity. The word 'large' refers to currents rather than voltages. Unlike crossover distortion 3b, the amount of lsn produced is significantly dependant on device characteristics.[3] The distortion residual is essentially third-order due to the symmetric and compressive nature of the output stage gain characteristic, but its appearance on a scope can be complicated by different amounts of nonlinearity in the upper and lower output stage halves.

Large signal nonlinearity occurs in both emitter-follower and complementary feedback pair output configurations; this article concentrates on the complementary feedback pair, as in **Fig. 3**. Incremental gain of a simulated complementary feedback pair output stage for 8 and 4Ω is shown in **Fig. 4**; the lower 4Ω trace has greater downward curvature, ie a greater falloff of gain with increasing current. Simulated emitter follower behaviour is similar.

As it happens, an 8Ω nominal impedance is a pretty good match for standard power bipolar junction transistors, though 16Ω might be better for minimising large-signal nonlinearity – loudspeaker technology permitting. It is presumably coincidental that the 8Ω nominal impedance corresponds approximately with the heaviest load that can be driven without large signal nonlinearity appearing.

Since large signal nonlinearity is an extra distortion component laid on top of others, and usually dominating them in amplitude, it is obviously simplest to minimise the 8Ω distortion first, so that 4Ω effects can be seen more or less in isolation when they appear.

The typical result of 4Ω amplifier loading was shown in Fig. 2, for the relatively modem *MJ15024/25* complementary pair from Motorola. **Figure 5** shows the same for one of the oldest silicon complementary pairs, the *2N3055/2955*, unfortunately on a slightly different frequency scale. The 8Ω distortion is similar for the different devices, but the 4Ω thd is 3.0 times worse for the venerable *2N3055/2955*. Such is progress...

Such experiments with different output devices throw use-

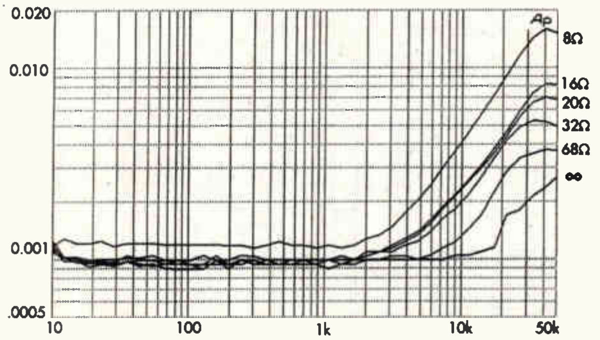


Fig. 1. Crossover distortion from a Blameless amplifier increases as load resistance falls to 8Ω. All plots at 80kHz bandwidth.

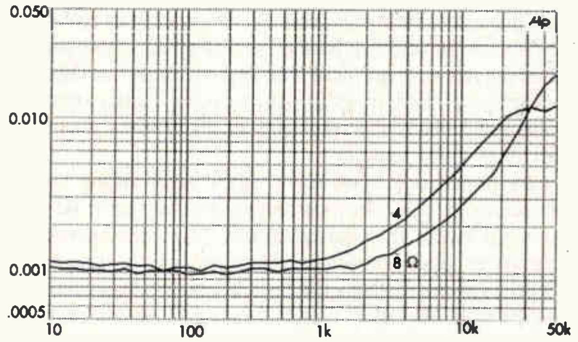


Fig. 2. Upper trace shows distortion increase due to large-signal nonlinearity as load goes from 8 to 4Ω. Blameless amplifier at 25W/8Ω.

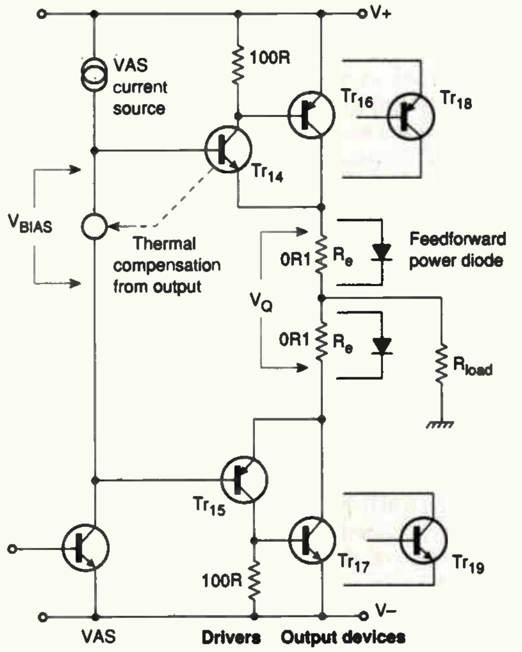


Fig. 3. Complementary feedback pair output stage, showing how extra devices are added in parallel, and where feedforward diodes would be fitted.

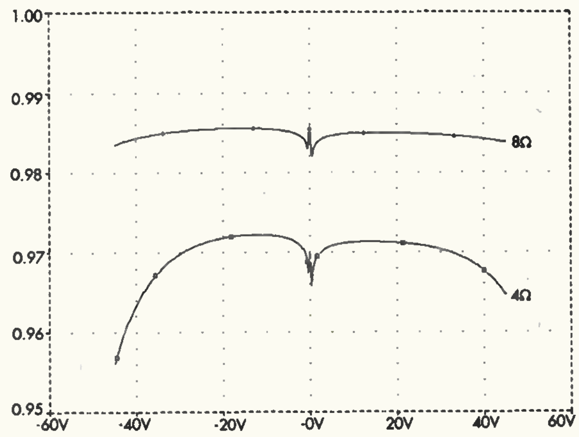


Fig. 4. Incremental gain of a standard complementary feedback pair output stage. The 4Ω trace droops much more as the gain falls off at higher currents. (PSpice)

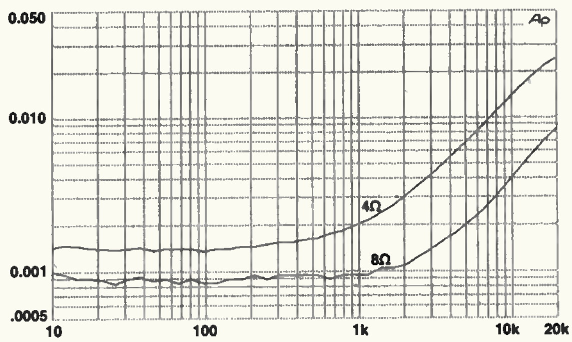


Fig. 5. Distortion with 4Ω load is 3x greater than 8Ω for 2N3055/2955 output devices. Compare Fig. 2.

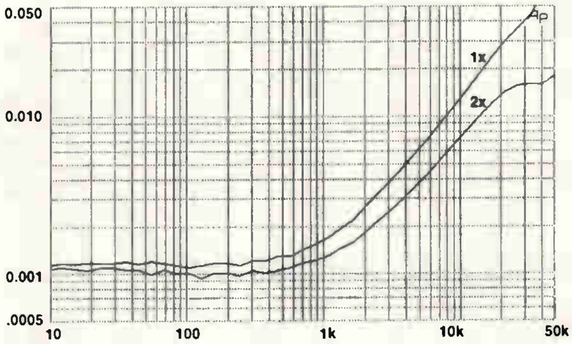


Fig. 6. Distortion with 4Ω load is reduced by 1.9x upon doubling standard MJ15024/15025 output transistors. 30W/8Ω.

ful light on the Blameless concept. From various types tried so far it can be said that Blameless performance, independent of output device type, should not exceed 0.001% at 1kHz and 0.006% at 10kHz, into 8Ω. All the components existed to build sub-0.001% thd amplifiers in mid-1969 – if only we had known how to do it.

Low-impedance loads have other implications beyond worsening the thd. The requirements for long-term 4Ω operation are severe, demanding significantly more heatsinking and power supply capacity if reliability is to be maintained.

For economic reasons the peak/average ratio of music is usually fully exploited, though this can cause real problems on extended tests, such as the FTC 40%-power-for-an-hour preconditioning procedure.

The main subject of this article is the extra distortion generated in the output stage itself by increased loading, but there are other ways in which the total amplifier distortion may be degraded by the increased currents flowing.

Table 1 shows the main distortion mechanisms in a power amplifier; Distortions 1, 2, and 8 are unaffected by output stage conditions. Distortion 4 might be expected to increase, as the increased loading on the output stage is reflected in increased voltage amplifier stage loading.[4] However, both the beta-enhanced emitter-follower and buffered-cascode methods seem to cope effectively with sub-8Ω loads.

The greater supply currents drawn could increase the rail ripple, which will worsen Distortion 5 if it exists. But since the supply reservoir capacitance must also be increased to permit greater power delivery, ripple will be reduced again and this tends to cancel out. If the rail ripple does increase, the usual *RC* filtering of bias supplies[5] deals with it effectively, preventing it getting in via the input pair tail, etc.

Distortion 6 may be more difficult to eliminate as the half-wave currents flowing in the output circuitry are twice as large, with no counteracting mechanism. Distortion 7, if present, will be worsened due the increased load currents flowing in the output stage wiring resistances.

Of those mechanisms above, Distortion 4 is inherent in the circuit configuration – though not a problem in practice – while 5, 6, and 7 are topological, in that they depend on the spatial and geometrical arrangements of components and wiring. The latter three can therefore be completely eliminated in both theory and practice. This leaves us with only the large signal nonlinearity component of Distortion 3 to grapple with.

The load-invariant concept

Ideally, the extra distortion component large signal nonlinearity would not exist. Such an amplifier would give no more distortion into 4Ω than 8, and I call it 'load-invariant to 4Ω'. The loading qualification is required because, as you will see, the lower the impedance, the greater the difficulties in aspiring to load-invariance.

I am assuming that we start out with an amplifier that is Blameless at 8Ω; it would be logical but pointless to apply the term 'load-invariant' to an ill-conceived amplifier delivering 1% thd into both 8 and 4Ω.

Large signal nonlinearity

Large signal nonlinearity is clearly a current-domain effect, dependent on the magnitude of the signal currents flowing in drivers and output devices, as the voltage conditions are unchanged.

A 4Ω load doubles the output device currents, but this does not in itself generate significant extra distortion. The crucial factor appears to be that the current drawn from the drivers by the output device bases *more* than doubles, due to beta fall-off in the output devices with increasing collector current. It is this *extra* increase of current due to beta-droop that causes almost all the additional distortion.

The exact details of how this works are not completely clear, but seems to be because the 'extra current' due to beta fall-off varies very nonlinearly with output voltage. It appears that the non-linear extra current combines with driver nonlinearity in a particularly pernicious way. Beta-droop is ultimately due to what are called high-level injection effects. These vary with device type, so device characteristics now matter.

As I stated in my original power-amplifier series[6], there is good simulator evidence that large signal nonlinearity is entirely due to the beta-droop causing extra current to be drawn from the drivers. To recapitulate:

- Simulated output stages built from output devices modified to have no beta-droop (by increasing Spice model parameter IKF) have no large signal nonlinearity. It seems to be specifically the extra current taken due to beta-droop that causes the trouble.
- Simulated output devices driven with zero-impedance voltage sources instead of transistor drivers show no large signal nonlinearity. This shows that such nonlinearity does not occur in the outputs themselves, but in the driver transistors.
- Output stage distortion can be regarded as an error voltage between input and output. The double emitter-follower emitter-follower stage error is driver V_{be}+output V_{be}+ R_e drop. A simulated emitter-follower output stage with the usual drivers shows that it is primarily nonlinearity in the driver V_{be} that increases as the load resistance reduces, rather than in the output V_{be}. The drop across R_e is essentially linear.

These three results have naturally been rechecked for this article.

Knowing that beta-droop caused by increased output device I_c is at the root of the problem leads to some solutions. Firstly, the per-device I_c can be reduced by using parallel output devices. Alternatively I_c can be left unchanged and output device types selected for the least beta droop.

Feedforward diodes across the emitter resistors sometimes help, but they treat the symptoms – by attempting distortion cancellation – rather the root cause, so it is not surprising this method is much less effective.

Doubled output devices

The basic philosophy here, indicated above, is that the output devices are doubled even though this is quite unnecessary for handling the power output required.

The fall-off of beta depends on collector current. If two output devices are connected in parallel, the collector current divides in two between them, and beta-droop is much reduced. From the above evidence, I predicted that this ought to reduce large-signal nonlinearity and when measured, indeed it does.

This sort of reality-check must never be neglected when you are using simulations. **Figure 6** compares 4Ω thd at 60W for single and doubled output devices, showing that doubling

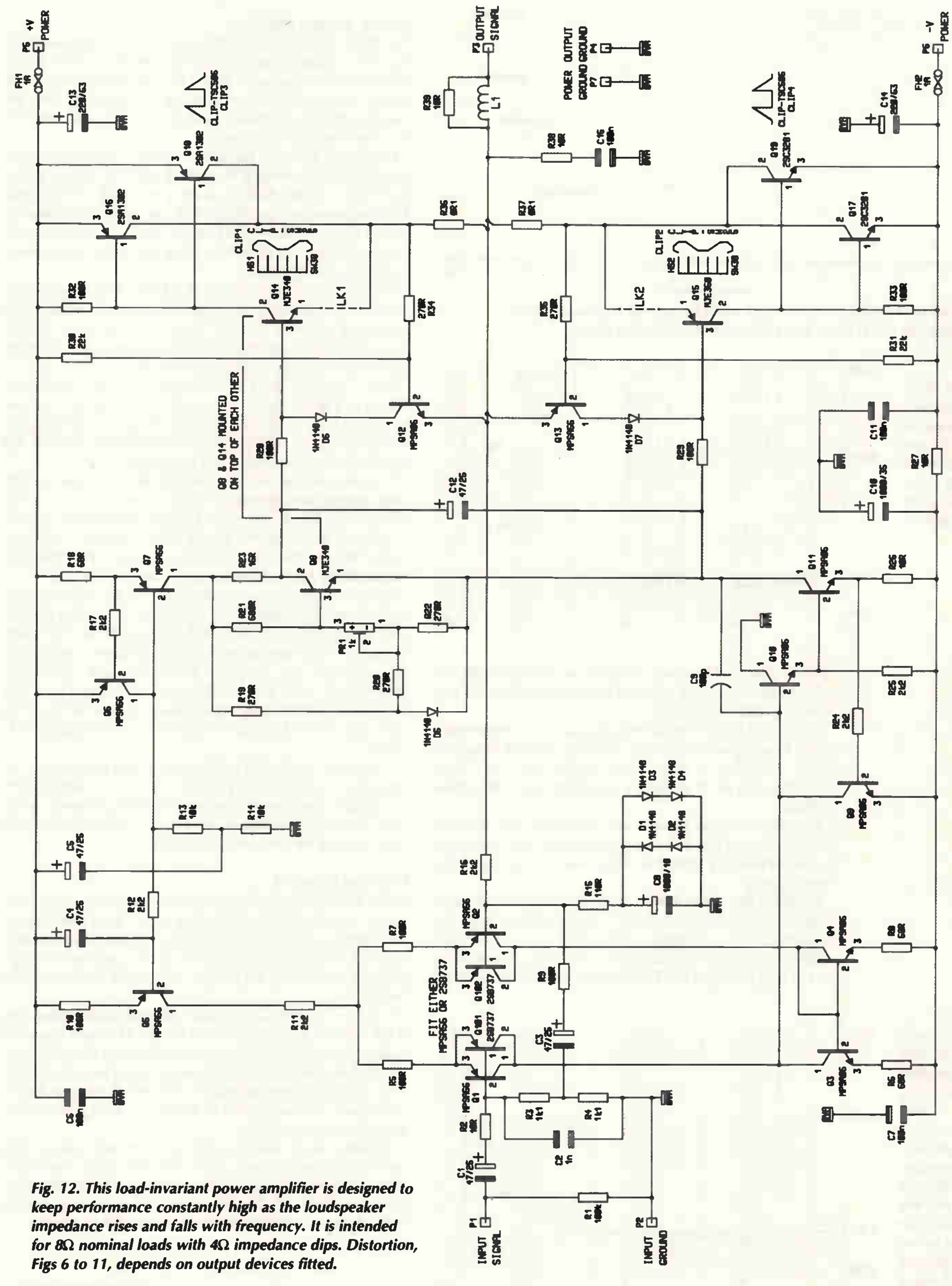


Fig. 12. This load-invariant power amplifier is designed to keep performance constantly high as the loudspeaker impedance rises and falls with frequency. It is intended for 8Ω nominal loads with 4Ω impedance dips. Distortion, Figs 6 to 11, depends on output devices fitted.

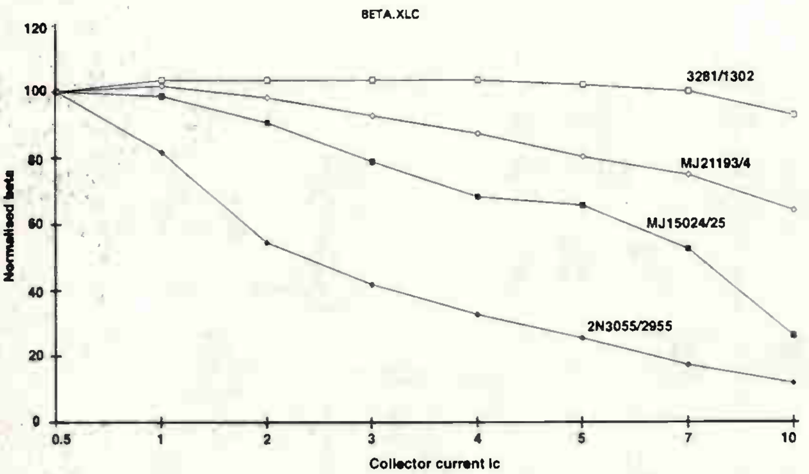


Fig. 7. Power transistor beta-droop as collector current increases. Beta is normalised to 100 at 0.5 A based on manufacturers' data sheets.

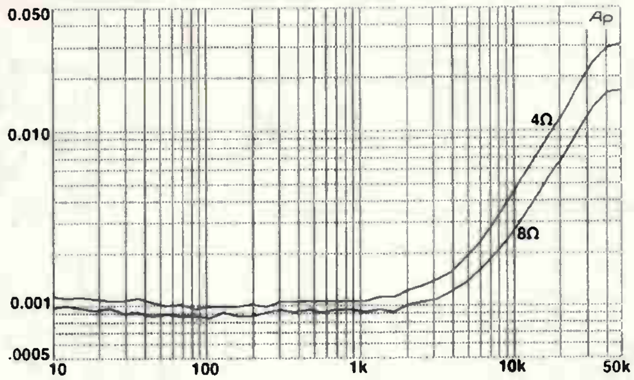


Fig. 8. Total harmonic distortion at 40W/8Ω and 80W/4Ω with single 3281/1302 devices.

reduces distortion by about 1.9 times; well worthwhile. The output transistors were standard power devices, in this case Motorola *MJ15024/15025*.

The *2N3055/2955* complementary pair give a similar halving of large-signal non-linearity on being doubled, though the initial distortion is three times higher into 4Ω. Those *2N3055*s with an H suffix are markedly worse than those without.

No current-sharing precautions were taken when doubling the devices, and this lack seemed to have no effect on large-signal nonlinearity reduction. There was no evidence of current-hogging.

Doubling the power devices naturally increases the power output capability, though if this is fully exploited large-signal nonlinearity will tend to rise again, and you are back where you started. It will also be necessary to uprate the power supply and so on. The essence of this technique is to use parallel devices to reduce distortion long before power handling alone compels you to do so.

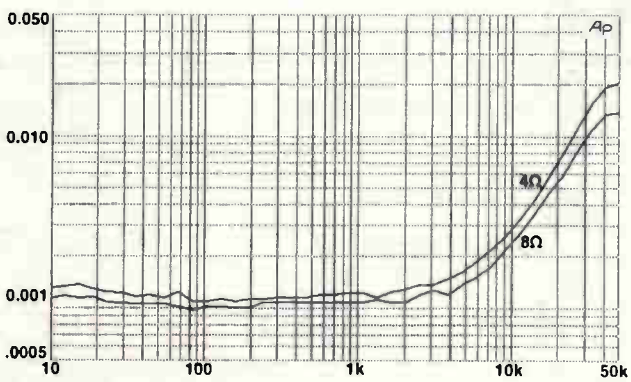


Fig. 9. At 40W/8Ω and 80W/4Ω with doubled 3281/1302 output transistors, the total harmonic distortion looks like this. 4Ω thd has been halved compared with Fig. 8.

Better output devices

The TO3P-packaged *2SC3281* and *2SA1302* complementary pair has a reputation in the hi-fi world for being 'more linear' than the run of transistors. This is the sort of vague claim that arouses the deepest of suspicions, and is comparable with the many assertions of superior linearity in power fets, which is the exact opposite of reality[7].

In this case however, the kernel of truth is that the *2SC3281* and *2SA1302* show much less beta-droop than average power transistors. These devices were introduced by Toshiba; Motorola versions are *MJL3281A* and *MJL1302A*, also in TO3P. **Figure 7** shows beta-droop, for the various devices discussed here, and it is clear that more droop means more large-signal nonlinearity.

The *3281/1302* pair is clearly in a different class from more conventional transistors as regards maintenance of beta with increasing collector current. There seems to be no special name for this class of bipolar junction transistors, so I have called them 'sustained-beta' devices here.

Into 4 and 8Ω, the thd for single *3281/1302* devices is shown in **Fig. 8**. Distortion is reduced by about 1.4 times compared with the standard devices of Fig. 2, over 2-8 kHz. Several pairs of *3281/1302* have been tested and the 4Ω improvement is consistent and repeatable.

The obvious next step is to combine the two techniques by using double sustained-beta devices. Doubled device results are shown in **Fig. 9** where the distortion at 80W/4Ω (15kHz) is reduced from 0.009% in Fig. 8 to 0.0045% – in other words halved. The 8 and 4Ω traces are now very close, the 4Ω thd being only 1.2 times higher than the 8Ω case.

Some similar devices exist. Other devices showing less beta-droop than standard are *MJ21193*, *MJ21194*, in TO3 packaging, and *MJL21193*, *MJL21194* in TO3P, also from Motorola. These devices show beta-maintenance intermediate between the 'super' *3281/1302* and 'ordinary' *MJ15024/25*, so it seemed likely that they would give less large-signal nonlinearity than ordinary power devices, but more than the *3281/1302*. This prediction was happily fulfilled.

It could be argued that multiplying output transistors is an expensive way to solve a problem. To give this perspective, in a typical stereo power amplifier, including heatsink, metal work and mains transformer, doubling the output devices will only increase the total cost by about 5%.

Feeding forward

In the Distortion in Power Amplifiers series, the only technique I could offer for improving large-signal nonlinearity was the use of power diodes across 0.22Ω output emitter resistors.[8] The improvement was only significant for high power into less-than 3Ω loading, and was of doubtful utility for hifi.

It is now my practice to make output emitter resistors R_e 0.1Ω, rather than the more usual 0.22Ω. This both improves voltage-swing efficiency and reduces the extra distortion generated if the amplifier is erroneously biased into Class AB.[8] Thus even with low-impedance loads the R_e voltage drop is very small, and insufficient to turn on a silicon power diode at realistic output levels.

Schottky diodes have a much lower forward voltage drop and might be useful here. Tests with 50A diodes have been made but have so far not been encouraging in the distortion reduction achieved. A suitable Schottky diode costs at least as much as an output transistor, and two will be needed.

Continued over page...

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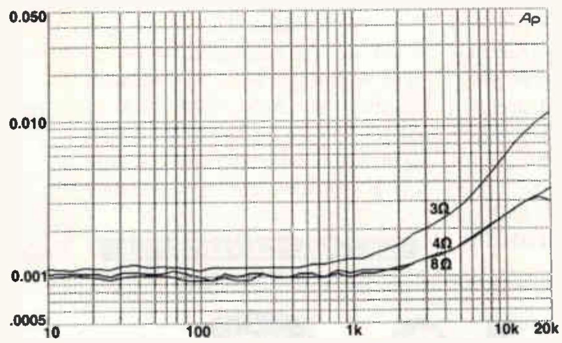

Fig. 10. Distortion for 3, 4 and 8Ω loads, single 3281/1302 devices. 20W/8Ω, 40W/4Ω and 60W/3Ω.

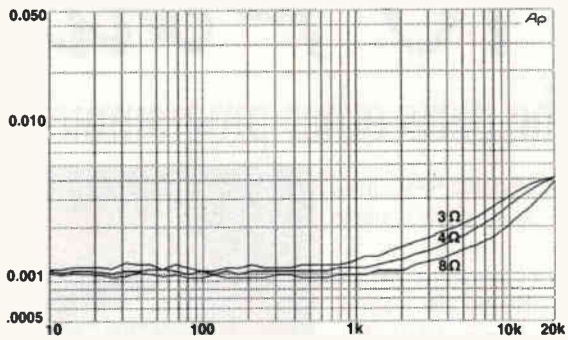

Fig. 11. Distortion for 3, 4 and 8Ω load, double 3281/1302 devices. Power as Fig. 10.

The trouble with triples

In electronics, there is often a choice between applying brawn – in this case using multiple power devices – or brains to solve a given problem. The 'brains' option would be represented by a clever circuit configuration that gave the same results without replication of expensive power silicon.

The obvious place to start looking is the various output-triple topologies that have occasionally been used. Note that 'output-triples' here refers to pre-driver, driver, and output device all in a local negative-feedback loop, rather than three identical output devices in parallel, which I would call 'tripled outputs'. Nomenclature is a problem.

In simulation, output-triple configurations do indeed reduce the gain-droop that causes large-signal nonlinearity. There are many different ways to configure output-triples. They vary in their general linearity and effectiveness at minimising large-signal nonlinearity.

The real difficulty with this approach is that three transistors in a local loop are very prone to parasitic and local oscillations. This is exacerbated by reducing the load impedances, presumably because the higher collector currents lead to increased device transconductance. This sort of problem can be very hard to deal with, and in some configurations appears almost insoluble. I have not studied this approach further.

Loads below 4Ω

So far I have concentrated on 4Ω loads; loudspeaker impedances can sink lower than this, so I pursued the matter down to 3Ω. One pair of *3281/1302* devices will deliver 50W into 3Ω for thd of 0.006% at 10kHz, **Fig. 10**. Two pairs of *3281/1302*s reduce this to 0.003% at 10kHz, **Fig. 11**. This is a very good result for such simple circuitry, and may be something of a record for 3Ω linearity.

At this point it seems that whatever the device type, doubling the outputs halves the thd percentage for 4Ω loading. The principle can be extended down to 2Ω operation, but tripled devices are required for sustained operation at significant powers. Resistive losses are serious, so 2Ω power output may be little greater than that into 4Ω.

Improved 8Ω performance

It was wholly unexpected that the sustained-beta devices would also show lower crossover distortion at 8Ω – but they do. What is more, the effect is again repeatable.

Possibly, whatever improves the beta characteristics has also somewhat altered the turn-on law so that crossover distortion is reduced; alternatively traces of large-signal nonlinearity, not visible in the thd residual, may have been eliminated.

Plot **Fig. 11** shows the improvement over the *MJ15024/25* pair; the 8Ω thd at 10kHz is reduced from 0.003% to 0.002%, and with correct bias adjustment, crossover artefacts are simply not visible on the 1kHz thd residual.

The artefacts are only just visible in the 4Ω case. To get a feel for the distortion being produced, and to set the bias optimally, it is necessary to test at 5kHz into 4Ω.

Implementing the load-invariant concept

Figure 12 shows the circuit of a practical load-invariant amplifier intended for 8Ω nominal loads with 4Ω impedance dips. Its distortion performance is shown in Figs 6 to 11, depending on the output devices fitted.

Apart from load-invariance, this design also incorporates two new techniques from the thermal dynamics series.

The first technique greatly reduces time-lag in the thermal compensation. With a complementary-feedback pair output stage, the bias generator aims to shadow driver junction temperature rather than the outputs. A much faster response to power dissipation changes is obtained by mounting the bias generator transistor Tr_8 on top of driver Tr_{14}, rather than on the other side of the heat-sink. Driver heat-sink mass is thus largely decoupled from the thermal compensation system, speeding up the response by at least two orders of magnitude.[9]

The second new technique is the use of a bias generator with an increased temperature coefficient, to reduce the static errors introduced by thermal losses between the driver and the sensor. Temperature coefficient is increased to –4.0mV/°C.[10] Diode D_5 also compensates for the effect of ambient temperature changes.

The design is not described in detail because much of it closely follows the Blameless Class-B amplifier described references 1 and 11. Some features are derived from the Trimodal amplifier.[8] Most notable of these is the low-noise feedback network, with its requirement for input bootstrapping if a 10kΩ input impedance is required. Single-slope *VI* limiting is incorporated for overload protection; see $Tr_{12,13}$.

As usual the global negative feedback factor is a modest 30 dB at 20kHz.

A point of departure

The improvements described here fit neatly into the philosophy of Blameless power amplifiers. The fundamental principle of the Blameless concept is that Distortion 3 should be the only significant distortion remaining. Distortions 1, 2 and 4 to 8 can all be reduced to negligible levels in straightforward ways.

For 8Ω operation, the main nonlinearity left is crossover distortion, which seems to vary only very slightly with output transistor type.

As I hoped, the concept of a Blameless power amplifier is proving extremely useful as a defined point of departure for new amplifier techniques. Starting from the standard Blameless Class-B amplifier, I have derived:

- The pure Class-A power amplifier[12]
- The Trimodal A/AB/B amplifier[8]
- The load-invariant amplifier described here
- A further new design to be announced...

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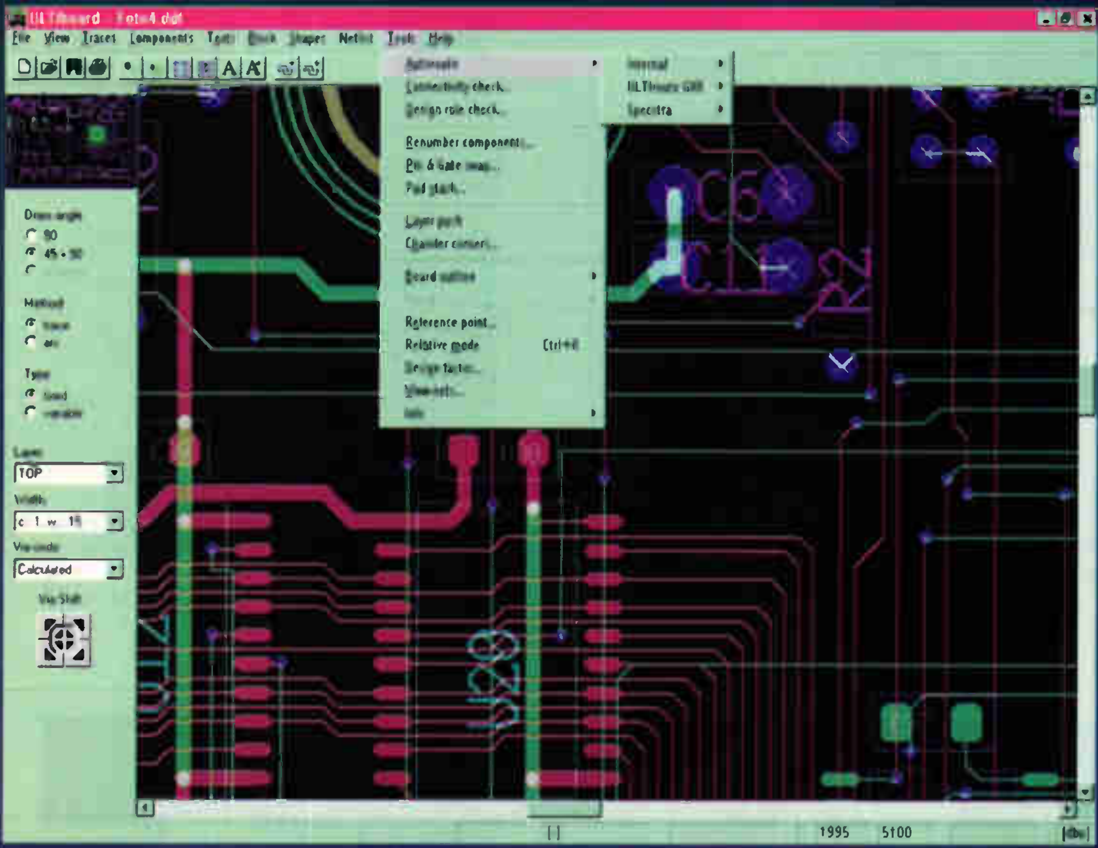

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Note that Trimodal and new load-invariant amplifier are simple add-ons to the basic Blameless Class-B configuration. The Trimodal design adds a Class-A biasing subsystem, and the new amplifier grafts on extra – or improved – output devices.

In summary

This study is incomplete in that the details of the large-signal nonlinearity mechanism remain incompletely understood, even though several practical methods for reducing it now exist. A detailed mathematical analysis would probably get to the bottom of it, but a foot-long equation usually gives little physical insight.

My initial thoughts were that an amplifier could be considered as load-invariant if the rise in thd from 8Ω to 4Ω was less than some given ratio. For normal amplifiers the thd increase factor is from two to three times. The actual figure attained by the amplifier presented here is 1.2 times. I, for one, am prepared to classify this as 'load-invariant'. The ratio could probably be made even closer to unity by tripling the outputs.

Remember that this amplifier is designed for 8Ω nominal loads, and their accompanying impedance dips; it is not intended for speakers that start out at 4Ω nominal and plummet from there. Nonetheless, I hope it is some progress towards load-invariance, and that power amplifier design might have taken another small step forward. ■

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Designer's power supply

Ian Hickman – who frequently designs circuits – shares his experience of power supplies and presents a solution combining versatility with features necessary for powering up a prototype without risking damage.

Of the various self-designed power supply units gracing my workbench, all but one provide only a single-rail. The exception is a dual 15V, 1A unit, with the facility for use as tracking ±15V supplies, as a 30V 1A supply or a 15V 2A supply. Perhaps because of this versatility, it is the one that I use most often, despite the fact that the current limit on each section is fixed at 1A.

Having experienced the inadequacies of my existing supplies, it seemed a good idea to take a fresh approach when designing a new one.

Useful features

An important feature is adjustable current limit. Additionally, in the interests of flexibility, I wanted my design to be easily modified to accommodate different output voltages and/or currents.

Since much of my work involves low-level analogue signals, in the interests of low noise, the design would be a linear regulator, with the inefficiency that this admittedly involves.

As the design would spend most of its working life powering circuitry under development, I placed emphasis on good performance in the constant voltage, or cv, mode, making very low hum ripple – even at full load – a priority. Performance in constant-current, or cc, mode is less important. Constant-current mode was intended primarily as a safety feature, to protect both the supply and the circuit being tested under fault conditions. Dual 15V supplies were envisaged, with provision for independent operation, operation in series, and operation with the voltage of one unit – the slave – automatically set to the same value as the other, acting as master. In this mode, the two units may be paralleled to provide double the current available from each separately, or connected in series to provide tracking positive and negative rails.

I adopted a fairly standard approach, Fig. 1, with a constant-voltage loop controlled by IC_1 and a constant-current loop by IC_2. With the wiper of R_v set to ground, i.e. fully clockwise, output voltage is determined by the ratio of R_f and R_i, and the voltage at the non-inverting input of IC_1. On the other hand, with the wiper of R_v set fully anticlockwise, if R_i/R_f equals R_a/R_b the output voltage will be zero.

In constant voltage mode, the constant-current loop is inactive, since the volt drop across the current sense resistor R_c is small compared with the voltage at the non-inverting input of IC_2.

Of course, Fig. 1 is purely diagramatic; in order for it to work, either the op-amps must have n-p-n open-collector outputs, or the output of each must be connected to the base of the pass transistor via a diode. Furthermore, there must be a dummy load across the stabilised output, to provide a pull-down for the emitter of the pass transistor at low output voltages. But apart from that, the scheme is plausible.

Specifications of the power supply

These specifications are for the basic 15V, 1A supply, but the design is versatile and is easily modified for other voltages and currents.

Output voltage	15V max. nominal
Continuously adjustable	0V to max output
Noise, hum and ripple	<100μVrms
Output current	1A max. nominal
Current limit continuously adjustable	From max. to 50μA
Noise, hum and ripple in constant current	<8mV peak-to-peak
Regulation	
Output resistance – not in current limit	50mΩ
Peak deviation	700mV*
Recovery time	10μs*
* for step load change 50% to 100% of rated current.	
Stabilisation	
Output voltage variation	1mV for ±10% mains voltage change

For the 15V 1A version, each mains transformer secondary, combined with the bridge rectifier and 2200μF reservoir capacitor, should be capable of delivering 21V dc at 1.3A continuously.

When it comes to the detailed design, practical difficulties emerge. Op-amps with open-collector outputs are not generally available. Although comparators fill the bill in this respect, they are notoriously unstable when operating in a linear regime.

Another problem with the Fig. 1 scheme is that the op-amps must be able to pull the base of the pass transistor right down to the negative stabilised output terminal while sinking the current from the constant current generator. But op-amps capable of this are limited as to the maximum supply voltage they can stand.

In the event, the ICs in Fig. 1 were realised with discrete devices. Using discretes provides you with much greater design flexibility.

My choices

My chosen design was based on Fig. 1, but with a number of variations. For instance, n-p-n current mirrors, such as the Texas Instruments *TL0xx* range, are readily available, but p-n-p mirrors are not.

In principle, you could use devices in a pack of matched p-n-p transistors from the *RCA CA3xxx* range, but the solution adopted here was to use a resistor supplying current from an auxiliary supply of voltage higher than the positive raw supply. The final circuit is shown in **Fig. 2.** A mains transformer from stock was used, providing a 21V raw supply. Allowing for about 2.5V peak-to-peak ripple across the reservoir capacitor C_3 at 1A full load, this transformer allowed a generous margin of V_{ce} for the pass transistor – even at –10% mains voltage.

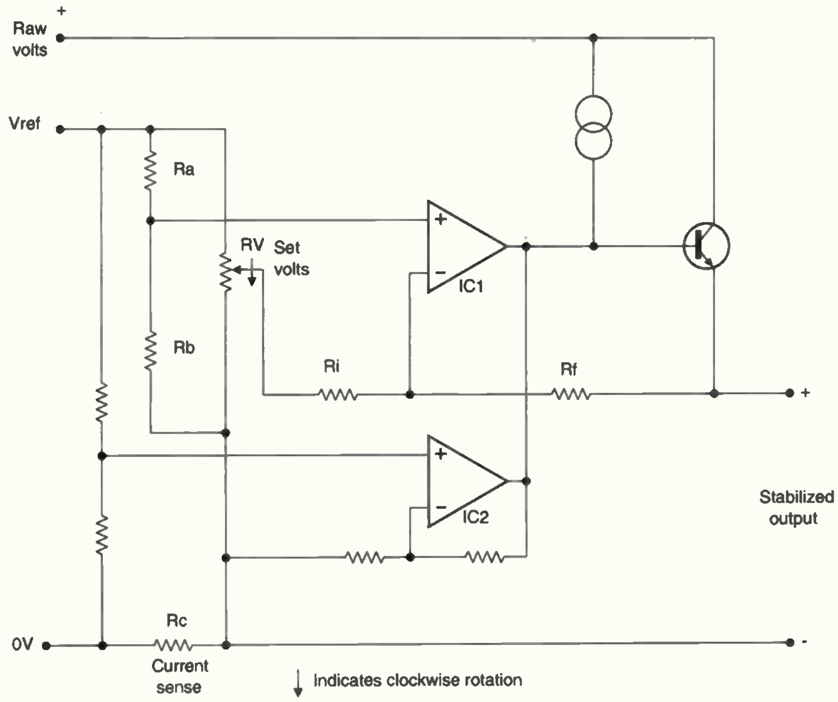


Fig. 1. Simplified circuit of a laboratory bench power supply.

The raw positive supply uses a bridge rectifier circuit as this makes the best use of the transformer's secondary copper. The modest size reservoir capacitor allows appreciable ripple voltage, resulting in lower copper losses due to a longer conduction angle than would apply with a larger reservoir. An additional half-wave doubler circuit provides the auxiliary supply.

Reference voltage is provided by an op-amp and zener circuit. This is a convenient arrangement using readily available devices, but you

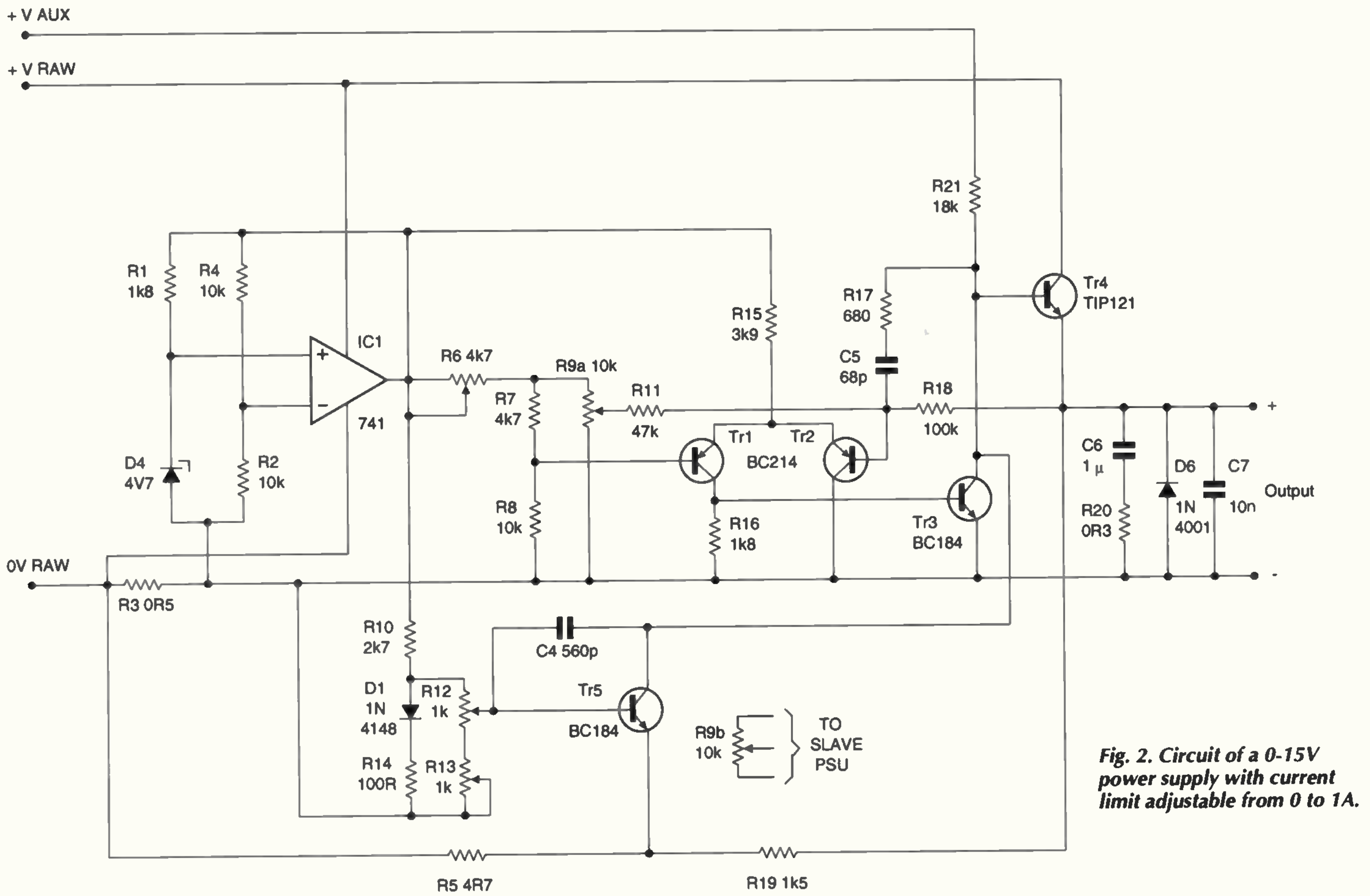


Fig. 2. Circuit of a 0-15V power supply with current limit adjustable from 0 to 1A.

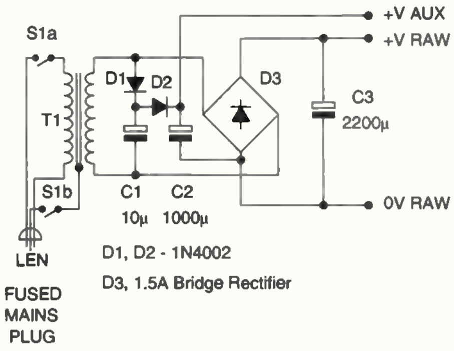


Fig. 3. Raw and auxiliary supplies. Two of these are needed, derived from separate secondaries and isolated from each other.

may prefer to use your own favourite IC voltage reference circuit, of which there are many on the market.

The op-amp provides the reference for both constant-voltage and constant-current loops. It also supplies tail current for the long tailed pair $Tr_{1,2}$. Together with Tr_3, these two replace of the IC_1 of Fig. 1.

Transistor Tr_3 drives the base of the pass transistor, a *TIP121* Darlington device which is adequate for a 15V 1A supply, given a generous heat sink. Actually, the 18kΩ resistor drives the pass transistor, Tr_3, simply sinking the excess current as necessary, to maintain the set output voltage. Capacitors $C_{6,7}$ maintain a low output impedance at frequencies where the loop gain starts to fall off. In conjunction with these, C_5 and R_{17} provide the necessary roll-off of loop gain for the constant-voltage loop. Resistors $R_{7,8,11,18}$ should preferably be 1% metal film, and R_6 permits the constant-voltage loop reference voltage to be set to 7.5V exactly.

In constant-voltage operation, Tr_5 remains cut off. At fully clockwise rotation of R_{12} its wiper is at the end of the track connected to R_{13}. This latter is set so that at an output voltage of 15V, the maximum available output current is, say, 1.1A. As R_{12} is rotated anticlockwise, the base voltage of Tr_5 rises. As a result, a smaller voltage drop across R_3 suffices to turn on Tr_5, limiting the available output current to a lower level. Transistors $Tr_{3,5}$ operate as a linear 'or' gate; whichever pulls the base of Tr_4 lower, that device controls the output voltage.

Constant current criteria

Unlike the constant-voltage loop, the loop gain of the constant-current loop is quite low. Such a low loop gain would result in the short-circuit output current being considerably greater than the maximum current available at output voltage of 15V.

This undesirable state of affairs is avoided by the judicious application of a little positive feedback from the output. The feedback is applied, via R_{19}, to the emitter of Tr_5, which is returned to the negative end of the raw supply via R_5. Thus as the output voltage falls, the additional drive, necessary to turn on Tr_5 harder, is supplied via its emitter. So an increase in output current, to provide an extra drop across R_3, does not occur. The result is that, with the component values shown, there is actually a small degree of 'fold back', that is to say that the short circuit current is actually slightly less than the maximum that can be supplied at an output voltage of 15V.

In addition, R_{19} plus R_5 form a dummy load, providing the necessary pull-down to enable the output voltage to be adjusted fully down to zero. In fact, on no-load, there is a residual output voltage of about 75mV – even when the demanded voltage is zero. This is due to some 50μA flowing via R_{11}, whose left-hand end is then at +7.5V, and R_{18}, producing the said drop across R_{19}. But this residual output voltage is of little consequence since the available current, into a short circuit, is of course no more than 50μA – even if the current limit setting of the constant-current loop be 1A.

Duals and slaves

The mains transformer used had two similar secondaries, **Fig. 3**. These powered two identical sets of raw and auxiliary supplies – completely isolated from each other – and two almost identical Fig. 2 type stabiliser circuits.

Figure 2 actually shows the master supply, R_9 being a two-gang linear 10kΩ potentiometer. Resistor R_{9A} controls the output voltage of the master unit. The corresponding 10kΩ potentiometer in the slave is a single gang unit, its track being in parallel with that of the second gang, R_{9B}, of the master unit.

In the slave unit, R_{11} is connected to a single-pole changeover switch. This enables the slave output voltage to be controlled either by its own single-gang R_9, or by the R_{9B} of the master unit. In the latter case, the output voltage of the slave tracks that of the master, enabling their outputs to be paralleled to provide up to 2A, or connected in series to provide tracking positive and negative supplies.

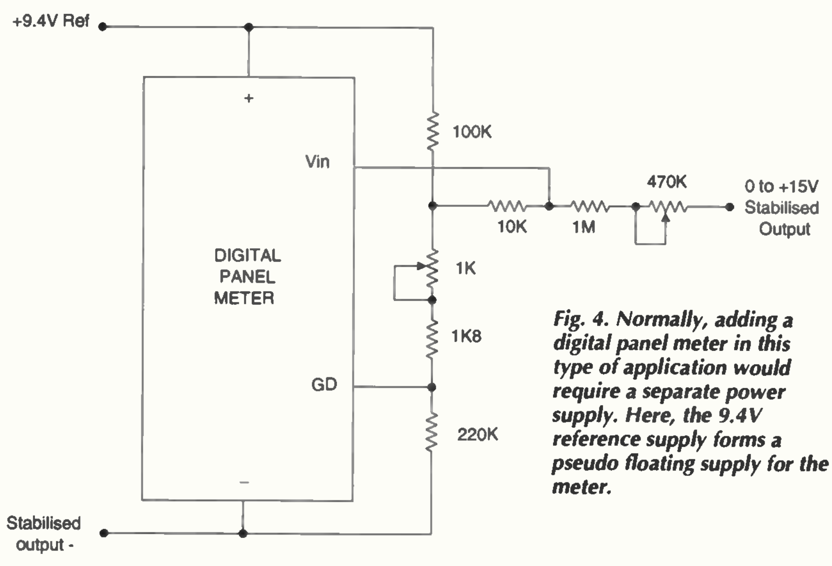


Fig. 4. Normally, adding a digital panel meter in this type of application would require a separate power supply. Here, the 9.4V reference supply forms a pseudo floating supply for the meter.

Metering outputs

Having a power supply with built-in metering is useful in that it frees up the dvm for other tasks. It is particularly convenient when checking a circuit under test for correct operation over the design supply voltage range, such as 4.75 to 5.25V. Digital panel meters are available at very attractive prices, so built-in metering is no longer a luxury*. One popular type is built around the *ICL7106CPL* chip, which is produced by a number of semiconductor manufacturers.

Such panel meters consist of no more than the IC, a liquid-crystal display and a dozen or so discrete components. Designed primarily for use in small free-standing digital voltmeters, the IC is usually powered by a standard 9V PP3 battery, drawing no more than a miserly 1mA.

The basic range of a digital voltmeter based on this chip is 200mV. Series limiters and shunts are needed for other voltage ranges, and for current reading. The 200mV input terminals are designated V_{in} and *GD*, the input

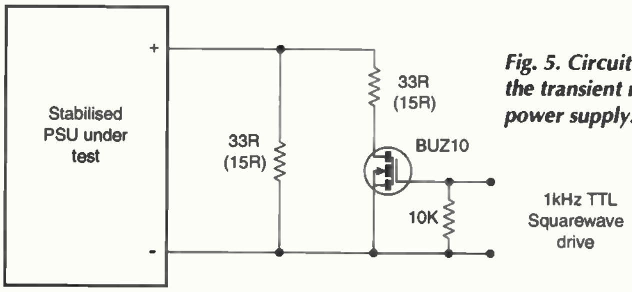


Fig. 5. Circuit used for testing the transient response of the power supply.

* One of the cheapest digital panel meters available in the UK, based on the *ICL7106* and available exclusively to *Electronics World* readers at a special price, is described on page 25.

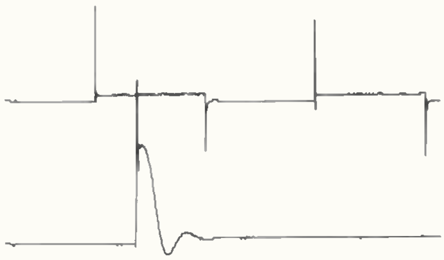


Fig. 6. Transient response of the power supply when the load switches between 0.5A and 1A; upper trace 200mV/div, 200µs/div: lower trace 200mV/div, 5µs/div.

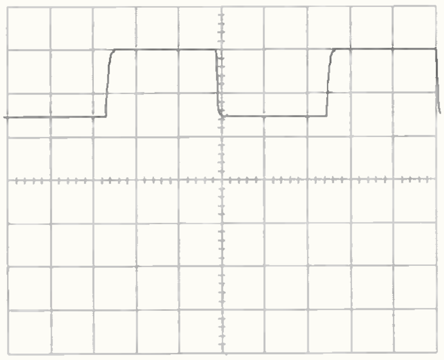


Fig. 7. Load switching between 33Ω and 17.5Ω, with the demanded output voltage set to 15V but the current limit reduced to roughly 0.5A, i.e. such that at 17.5Ω the voltage collapses to 7.5V; 5V/division, centre line = 0V, 200µs/division.

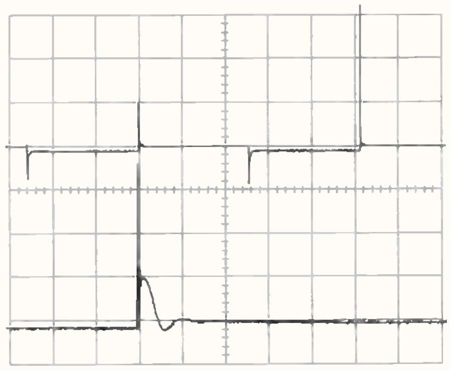


Fig. 8. Transient response of the psu when the load switches between 1A and 2A; upper trace 500mV/div, 200µs/div: lower trace 500mV/div, 5µs/div

resistance between them being more than 100MΩ.

However, the common-mode input resistance between these terminals and the negative end of the +9V supply is undefined. The IC is normally operated with the 9V battery floating, the *GD* terminal sitting at about two thirds of the supply voltage, or +6V. Though high, the common-mode input resistance is by no means to be ignored, being non-linear to boot. If the *GD* terminal is tied to a fixed voltage other than that at which it normally floats, the display shows the overload indication as a lone '1' in the left hand digit.

On the other hand, the need to supply a floating +9V is clearly an inconvenience for the designer. However, it turns out that with a little ingenuity, the 9.4V reference supply to the constant-voltage and constant-current loops can be pressed into service.

Figure 4 shows the scheme: the reference supply is used as a pseudo-floating supply by translating and scaling the 0 to 15V output to be measured to a 200mV range at the *7106*'s natural common-mode input voltage. This is carried out at a high impedance level – possible in view of the panel-meter's very high input resistance – thus avoiding pulling the common mode input voltage away from its preferred level.

The resistance values required are not what you would calculate on the basis of an infinite common-mode input resistance. The proper values are in fact not easily derived, given the non-linear common mode input resistance. As a result, I made them adjustable via trimmer potentiometers. These were set to give the right readings at output voltages of zero and +15V.

As the adjustments interact, they must be iterated to achieve the correct final settings. Adjusted thus, the panel meter agreed with the readings on a Philips *PM2521* dvm to well within ±1% over the whole 0 to 15V range. The dvm was reading the actual 0 to +15V output of the power supply, while the dpm saw a 0 to 150mV input. But linking the appropriate points on the rear pcb of the panel meter, namely jumper P2, activates a decimal point to indicate a 00.00 to 19.99 range.

Three samples of panel meter were tested in

Tips on power supply use

With one or two amps of current available at whatever output voltage has been set, up to 15 or 30V, there is always the possibility of damage to a newly constructed prototype circuit connected to the power supply, when first powered up.

Some engineers are supremely confident of their design and workmanship, and thus have no qualms. For my part, there is always the worry that some misconnection – or even more likely, an undetected solder bridge – will result in the damage or destruction of one or more devices.

A safe way of powering up in such circumstances is to make use of the continuously variable current limit. The supply is set to the desired output voltage, and the current limit control then set fully anticlockwise, causing the output voltage to collapse to zero. The current meter is then set to a range appropriate to the current which the circuit under test is expected to draw, and circuit under test connected to the power supply.

The current limit control can now be advanced slowly clockwise, keeping a weather eye on the current meter and another on the voltmeter. If the current starts to rise alarmingly before the output voltage is anywhere near the preset value, it is prudent to switch off and recheck the circuit under test for faults. If the power supply is to be used in this way, it is advisable to use a reliable long-life potentiometer for the current limit control R_{12}, such as a cermet type.

There is an alternative mode of use, which though not offering such certain safety, will usually prevent any damage. This mode is useful where the supply is to be used by all and sundry. This is to fit an on/off switch for the power supply output, independent of the mains on/off switch. Downstream of this switch is a 100µF capacitor and discharge resistor, as in **Fig. 10**.

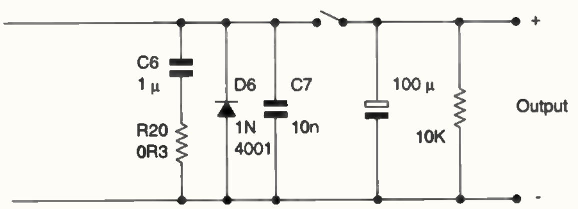


Fig. 10. When the separate output switch is closed, the 100µF capacitor causes the output voltage momentarily to collapse almost to zero. Output voltage then ramps up with the power supply in current limit, until the preset voltage is reached, or until the limited available current is drawn through a fault in the circuit under test.

At switch-on, charge sharing between C_6 and the 100µF capacitor causes the output voltage to collapse to 1% of the preset value, e.g. 15V down to 150mV. The output voltage then ramps up at the set current limit until either the preset output voltage is reached, or the fault current drawn by the circuit equals the current limit.

If the fault current is only tens of milliamps – more than adequate to power a good deal of c-mos circuitry – usually no permanent damage will result, and the fault can then be cleared at leisure.

the circuit of Fig. 4. Only minor readjustments of the trimmer potentiometers were needed for each.

Current indication

A second panel meter can be used as a dedicated current meter, but an op-amp stage would be needed to suitably scale and translate the 0 to 500mV developed across R_3 to the desired level. But my personal preference for a dedicated current meter is a moving coil analogue type, since this provides an instantaneous visible indication of the current drawn. A versatile, fully protected circuit is described later on.

Using a digital panel meter, with its reading rate of about three readings a second, and allowing for settling time, a clear indication of the current drawn would not be instantly available. Indeed, if the current being drawn by the load has an appreciable ripple, the last few digits may be constantly flashing.

An analogue meter, by contrast, has a degree of built-in smoothing, due to the inertia of the movement. Nevertheless, a digital readout of current can be useful for testing purposes, so perhaps the best of both worlds would be an analogue meter permanently indicating the current being supplied, and a digital meter normally indicating output voltage, but switchable by means of a biassed toggle, to read current when required.

A useful performance

I tested the 15V 1A power supply of Figs 2 and 3 for the usual performance parameters, with the following results.

Direct-current output resistance measured 50mΩ, while the change in output voltage for a 10% change in mains voltage was barely 1mV. Output ripple in constant-voltage mode, supplying 1A at 15V, was estimated at around 200μV peak-to-peak, as measured on the 2mV/division range of a Thurlby-Thandar digital sampling adaptor type *DSA524* with averaging mode selected.

In view of the low signal level, to avoid possible errors due to earth loops, the reading was repeated, using the audio-frequency millivoltmeter section of the laboratory amplifier described in Ref. 1, with its balanced floating input stage. There was no indication on the 3mV rms full scale range, confirming that the full load ripple is below 100μV rms.

With the same load resistance and set voltage, the current limit was reduced to enter constant-current mode. Ripple voltage across the load was then 8mV pk-pk at 900mA, reducing *pro rata* with current, reflecting the lower gain of the constant-current loop.

An important parameter of a power supply is the transient response when the demanded load current changes abruptly. **Figure 5** shows a simple test circuit which was used to switch the load between 0.5A and 1A approximately, at a rate of 1kHz. The transient was captured using the *DSA524*. The result is illustrated in **Fig. 6**, at 200μs/division, upper trace, with an expanded view of the transient at 5μs/division, lower trace.

When the load drops from an amp to half an amp, there is a momentary positive-going spike of some 700mV. But since the width of this measured out at just 100ns, the energy associated with it is low. Thereafter, there is a well-controlled transient, settling within 10μs to the steady level.

The story when the load switches from 0.5A to 1A is similar; the spike just looks smaller in the upper trace as a sampling pulse does not happen to have caught the peak. **Figure 7** shows the same load and set voltage, but with the current limit set to roughly 0.5A, so that at the lower value of resistance, the output voltage drops to 7.5V. The response is overshoot-free, as the constant-current loop is, if anything, overdamped.

The prototype is stable both on and off load in both constant voltage and constant current modes with 1000μF in parallel with the output. Of course, a 1000μF capacitor reduces the 7.5/15V switching waveform of Figure 7 to pretty well an 11V straight line, and even just 10μF turns it into something approaching a triangular wave.

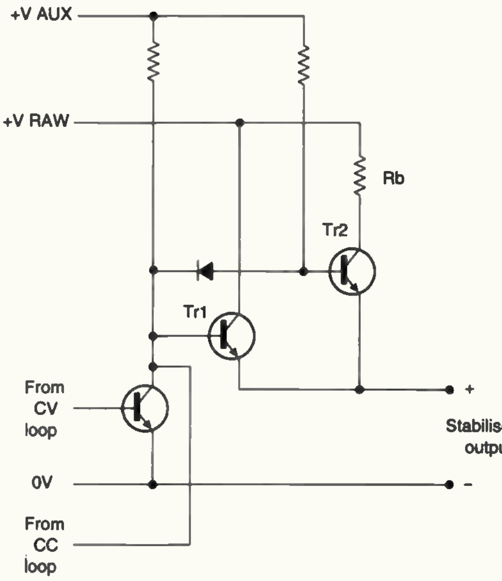


Fig. 9. Updated version of the McPherson regulator. Of the worst case total dissipation, only around a third ever appears in either output transistor.

Variations on a theme

As mentioned in the introduction, the circuit is designed to be 'stretchable', both in voltage and current. Typical ratings for commercial laboratory bench power supplies are 15V or 30V, at 1A, 2A or occasionally 5A.

Figure 8 shows the output of the psu when the load switches between 1A and 2A, the 33Ω resistors in Fig. 5 having been replaced by similar wirewound 15Ω resistors. As the raw supplies with pass transistor Tr_4 and its heat sink were not rated for continuous use at 2A, the test was not continued for longer than necessary to obtain the results shown.

To enable the unit to provide 2A, even in the short term, current sensing resistor R_3 was temporarily shorted to defeat the current limit – not a practice to be recommended. A proper 2A version requires only the beefing up of the raw supplies, a pass transistor with a higher maximum dissipation than the *TIP121* used in Fig. 2 – with suitable extra heatsinking – and halving the values of R_3 and R_{21}.

Similarly, few changes are required for a 30V version, other than attention to voltage

Supplying the panel meter

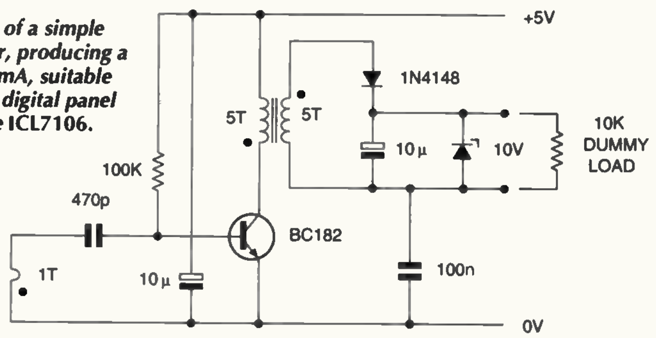
The stratagem described in the main article, to permit the panel meter to be powered from a non-floating supply, is not always convenient. In this case, an inverter can be used to produce a suitable floating 9V supply from whatever rail voltage is available.

Figure **11** shows a very simple flyback inverter for operating a digital panel meter from a +5V rail. At under 60%, the efficiency when supplying close on 10V at 1mA, is not wonderful. However, the odd 3.8mA is hardly a heavy load on the 5V supply.

The prototype circuit ran at about 170kHz, producing 9.52V off load, 9.46V into a 10kΩ dummy load simulating a digital panel meter. The dual five-turn windings were of bifilar wire, on a Mullard *FX2754* two-hole balun core having an A_L of 3500nH/turn^2.

Direct-current-wise, the output voltage is floating, but the 100nF capacitor is added to prevent switching frequency ripple appearing on the output relative to ground. The circuit is readily adapted for other supply voltages, and as the required output power is less than 10mW, efficiency will not usually be an important consideration.

Fig. 11. Circuit of a simple flyback inverter, producing a nominal 10V 1mA, suitable for powering a digital panel meter using the **ICL7106.**



ratings of capacitors and semiconductors – and one other point. If you are using a $3^1/_2$-digit panel meter in a 30V version, provision must be made to switch the latter from 19.99V full scale to 199.9V full scale. A useful halfway house, providing more than 15V output but without the complication of dpm range switching, is a 20V design. This will enable circuitry designed for either 15V or 18V nominal supplies to be tested at both top and bottom supply limits.

Whatever the rating chosen, a useful feature to incorporate is a non-locking push-button wired across the output terminals. Pressing this will put the psu into current limit, and R_{12} can then be adjusted for a lower limit than the maximum, if required.

More variations

The *TIP121* Darlington is so cheap and convenient, it is worthwhile considering whether it can be used in higher power designs. For example, in a 15V 2A design, two can be used in parallel. Each needs to be fitted with a 0.5Ω emitter ballast resistor to prevent current hogging by one of them. Heatsinking must be adequate to handle the total worst case dissipation, with a short circuited output and the highest mains voltage. However, the two devices are equivalent to a single Darlington with half the junction-to-heatsink thermal resistance of a single device.

For even higher powers, the McPherson circuit, Ref. 2, is attractive. Its patent has probably by now expired. An updated version of

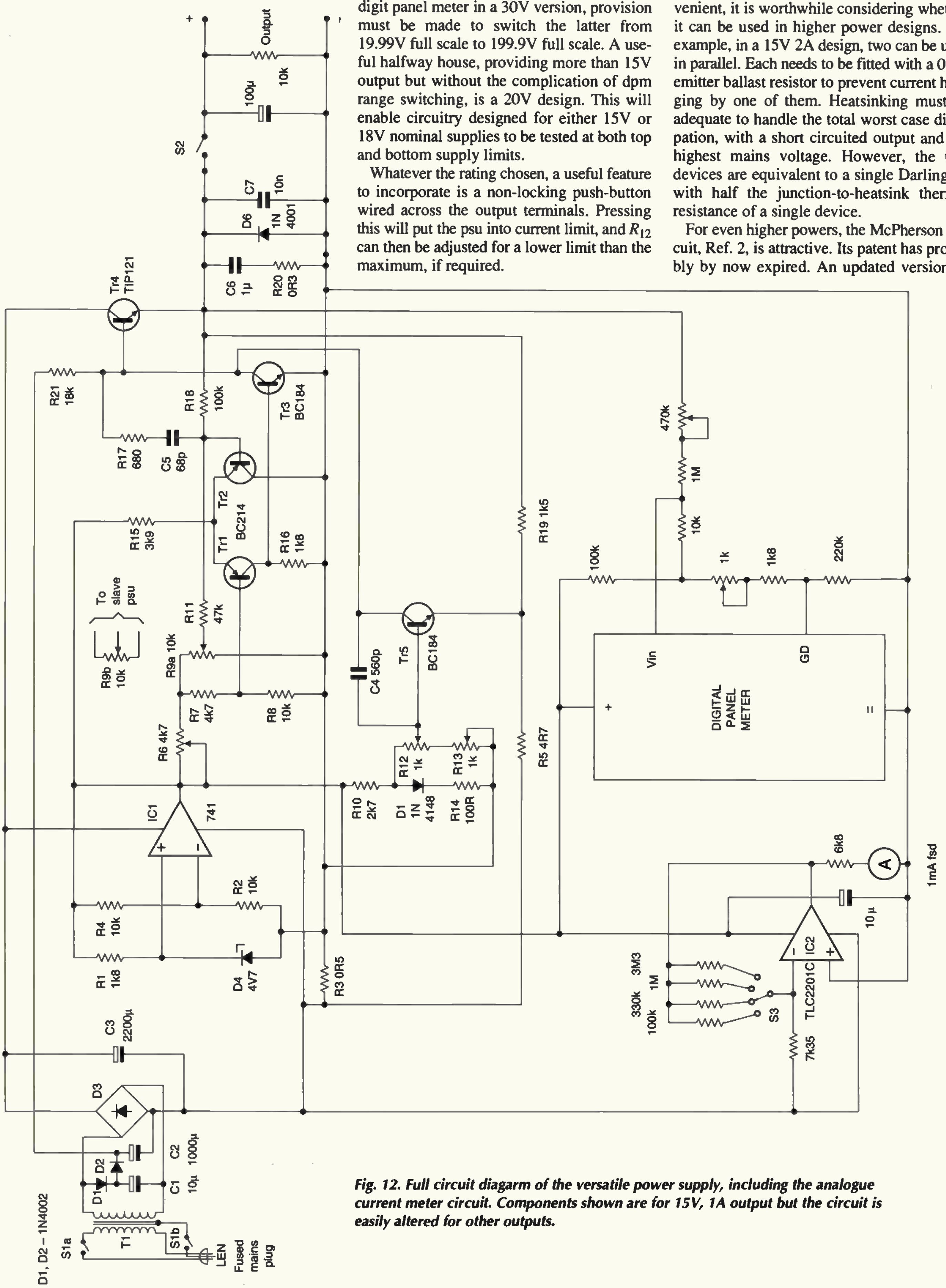


Fig. 12. Full circuit diagarm of the versatile power supply, including the analogue current meter circuit. Components shown are for 15V, 1A output but the circuit is easily altered for other outputs.

this scheme is shown in **Fig. 9**. If you imagine the raw voltage to be only marginally greater than the maximum rated output voltage, for example at minimum mains voltage, then only a quarter of the worst case power dissipation ever appears in either transistor; often it is much less. This is because at rated maximum current on short circuit, Tr_1 is cut off, Tr_2 bottomed, and all the dissipation takes place in ballast resistor R_b, which is $V_{rated(max)}/I_{rated(max)}$. At maximum rated current at maximum output voltage, Tr_2 can make no significant contribution, so all the current is supplied via Tr_1, whose V_{ce} is then however minimal.

There are two worst cases; the first is full output current at half output voltage. Here, Tr_2 is bottomed and supplies half the current, while Tr_1 supplies the other half, with a V_{ce} of half the raw volts. The other is negligible output voltage at half rated current. Here, Tr_1 is off and Tr_2 supplies half the rated current with half the raw volts collector to emitter. Either way, only a quarter of the maximum power dissipation appears in either transistor, and never in both at the same time, so they can usefully share the same heatsink.

In practice, the worst case transistor dissipation is somewhat more than this, especially at top mains voltage. But it is still much lower than schemes where all the dissipation occurs in pass transistors. Clearly, a considerable saving in the heat sinking requirements is achieved. Most of the dissipation occurs in the wirewound resistor, or resistors, which can handle heat at a 300°C surface temperature, against 125°C for a semiconductor junction.

Reference 2 describes how the scheme can be extended to four transistors, three with appropriate value resistors in their collector circuits. Turning on one or more, as required, in sequence, keeps most of the dissipation in the various ballast resistors, a very effective arrangement.

Variations on the current limit circuit are also possible. **Figure 10** shows a versatile analogue current meter circuit. An op-amp is used to amplify the 0.5V maximum drop across the current sense resistor R_3 to 6.8V, to drive a 1mA full-scale deflection meter, scaled 0 to 1A and 0 to 300mA.

Other values of feedback resistor may be selected, giving a choice of 30, 100, 300 and 1000mA ranges. On the most sensitive of these, the full-scale voltage drop across R_3 is only 15mV, so an op-amp with low offset voltage is indicated.

A *TLC2201/C* being to hand, this device – with its typical offset of 100μV – was used. In fact, with its low maximum input offset of 500μV (or 200μV on the /AC and /BC versions), the *TLC2201* comes without offset adjust inputs, and at 1pA its bias current is not large either. But a more mundane op-amp, complete with offset adjustment, would suffice.

The circuit shown protects the meter against overload. If the psu supplies 1A when the meter is switched to the 30mA range – representing a 33× overload – the op-amp output can only reach something less than +9.4V, limiting the actual meter overload to less than 50%.

Another variation can be useful, where the maximum power available from the raw supply at +7% mains voltage, is greater than the pass transistor can dissipate indefinitely with the output short-circuited. For example, on a 15V 1A unit, the current limit could be set at 1.5A at 15V, folding back to 1A when the output is shorted. This merely involves raising the value of R_5. A further ploy is to thermally couple Tr_5 to Tr_4; the short circuit current can then be set to, say, around 1.2A with the unit cold. On an extended short circuit, the V_{be} of Tr_5 will then fall by about 2.2mV/°C as the heatsink and pass transistor warm up, gradually reducing the short circuit current back to 1A.

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1. Hickman, I, Listening for clues *Electronics World* July/August 1996 pp 596-598.
2. McPherson, J W, Regulator Elements Using Transistors *Electronic Engineering*, March 1964, p. 162.

Speakers' corner

Two loudspeaker technologies are investigated here, one involving coincident ultrasonic beams, the other a complex resonant panel. Neither is new, but both have seen recent advances that bring them nearer to commercial realities. Richard Ball leads off with a report on the flat panel.

Since the advent of audio reproduction attempts have been made to manufacture loudspeakers that are flat and unobtrusive.

Some of the first commercially successful flat loudspeakers were made by Quad, appearing in production in the late fifties. In appearance they were similar to, and only slightly smaller than, a folded deck-chair.

Loudspeakers such as these contained a charged plate or foil suspended between two perforated metal sheets. The outer sheets were held at a high voltage with changes in this voltage causing the plate to move, creating an acoustic wave.

Unfortunately, for low distortion, the whole system had to be nigh on perfectly symmetrical. This was a problem for manufacturing techniques at the time – and probably still would be today. The physical nature of the plates also meant they were limited in their frequency response. Like conventional cone speakers, two or more were needed to cover the entire audio frequency range.

These speakers suffered from some significant disadvantages. They were difficult to manufacture, expensive and potentially dangerous because of the high voltages needed to operate them successfully. Other attempts at making flat loudspeakers failed simply due to poor quality of sound. Consequently, perceived wisdom is that loudspeakers have to be boxes with conventional driver units inside.

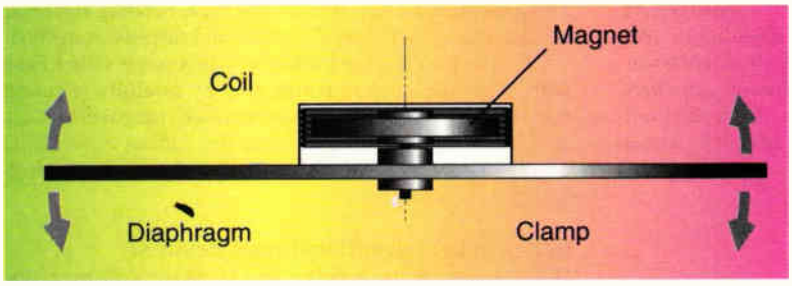
Good response with no enclosure?

Now, a UK company has developed a fresh approach which could change the audio industry's views.

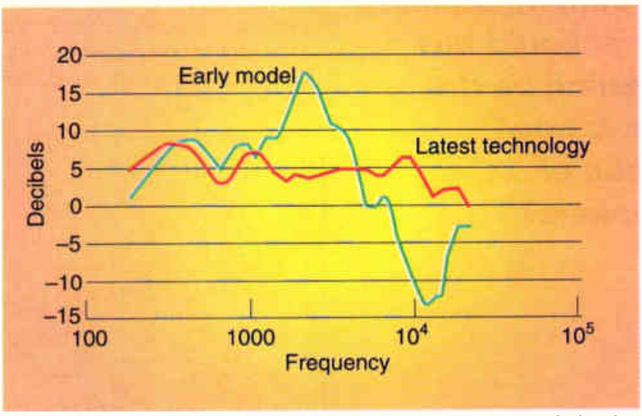
NXT is a newly formed division of Verity, the parent company of Mission, Quad and Wharfedale. It has developed the distributed mode loudspeaker, or dml, which is a flat panel claimed to efficiently and effectively radiate sound over audio frequency ranges.

The distributed-mode loudspeaker was developed by Verity's V-labs – now NXT – from an original idea by the Defence Research Agency. Engineers at the DRA were looking at the possibility of using panels as acoustic noise dampers in military aircraft cockpits. Perversely these panels had the reverse effect – they increased the sound.

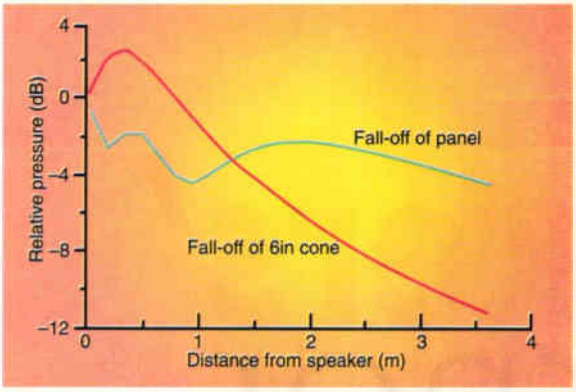
Initial research into using the panels as speakers met with little success. Hence the technology was licensed by NXT some two years ago. NXT was able to capitalise on the DRA work because of the availability of modern computers and workstations capable of modelling the complex patterns of vibrations produced in panels that are flexing.



This diagram shows a cross-sectional view of the loudspeaker with one of the possible driving arrangements. A magnet and a coil are separately clamped to the panel. As current in the coil changes, the panel is forced to bend, creating extremely complex ripples in the panel's surface. Fourier analysis is used to determine the best position for the driver on the panel. Transducers such as this can be produced to standard four or eight ohm impedances. As well as this type of electrodynamic driver, distributed-mode loudspeakers can also be driven by piezoelectric transducers. As piezo devices are high voltage low current, speakers requiring louder outputs may require matching transformers for compatibility with conventional audio amplifiers.



This graph demonstrates the improvements distributed-mode loudspeakers offer over the electrostatic type of flat speakers. The distributed-mode loudspeaker shows a sound level variation of 8dB between 200Hz and 20kHz. The electrostatic speaker shows a far greater variation. The distributed-mode loudspeaker does not show any improvement or otherwise over conventional loudspeakers, except perhaps at higher frequencies.



One of the more interesting results of NXT's work is the sound pressure output over distance. Drop-off is claimed to approximate a linear relationship rather than the inverse square law of conventional drivers. This feature, when combined with larger panels up to 100m², would enable much more efficient loudspeakers for public address and concert applications. Not only would lower power amplifiers be needed, but electricity would be saved too.

The distributed mode concept

A distributed mode loudspeaker panel is built with a thickness ranging from 3 to 25mm – hence it is stiff. When the panel is excited by an external force, such as the output from an amplifier coupled via a magnet and coil, as in the diagram, a complex set of waves measuring in the order of a few micrometres is set up on the surface. The complex modes of oscillation set up in the panels are analysed using Bessel functions and finite-element analysis.

NXT carried out extensive work on the panels, making many subtle changes to their parameters. This research has led to a set of factors defining the behaviour of a panel. These include: surface density and area, bending stiffness, panel geometry, drive point location and suspension method.

Stiff, flat panels do not inherently produce a sound field with a flat frequency response. But, by carefully selecting correct parameters for all factors involved, the panel will act as a loudspeaker. This is because the various movements cause sound waves which constructively interfere when detected at a distance.

Better than conventional cone devices?

Distributed-mode loudspeakers are claimed to score over conventional cone and other flat speakers in several respects.

The panel is designed such that sound from the two sides of the panel is in-phase. It is bi-polar. This means no enclosure or box is needed to cancel half the sound, immediately making the panel 3dB more efficient than conventional enclosed speakers – which are dipoles.

One critical area in which NXT has improved the original design is that of frequency range. The DRA managed a one and a half decade range. NXT has extended this to two and a half decades – adequate for audio loudspeaker applications. At present, the widest frequency range that can be consistently manufactured in a prototype panel is 60Hz to 18kHz.

However, bass response deepens and maximum sound level improves with size. Maximum size is over 100m², so the possibilities look good for public address and concert sound systems.

This reasonably wide frequency range of distributed-mode devices allows for just one speaker and associated drive electronics. Conventional speakers suffer from requiring two or more cones plus crossover networks for a reasonable quality of output. This results in increased cost and complexity. Over the given frequency range, response is comparable to conventional speakers although NXT does not specify what type or quality of speaker is used for comparison.

Conventional theory assumes that loudspeakers, or multiples thereof, are seen as point sources. This leads to the sound level dropping off with distance as an inverse square law. According to NXT, its speakers have a more complex intensity/distance relationship which approximates to a linear law – the sound level remains higher than conventional speakers as one moves away as shown in one of the two graphs.

Theory of flat loudspeakers suggests that this may be so – though possibly only close to the speaker under near field conditions – and also indicates that the effect is different for low or high frequencies.

Maximum sound-pressure level is not a property that has been fully explored by NXT. In principle, the company says, there is no limit to loudness except that due to temperature considerations of the drive transducers. To counteract heating effects, the company suggests that the entire panel be used as

Sonics from ultrasonics

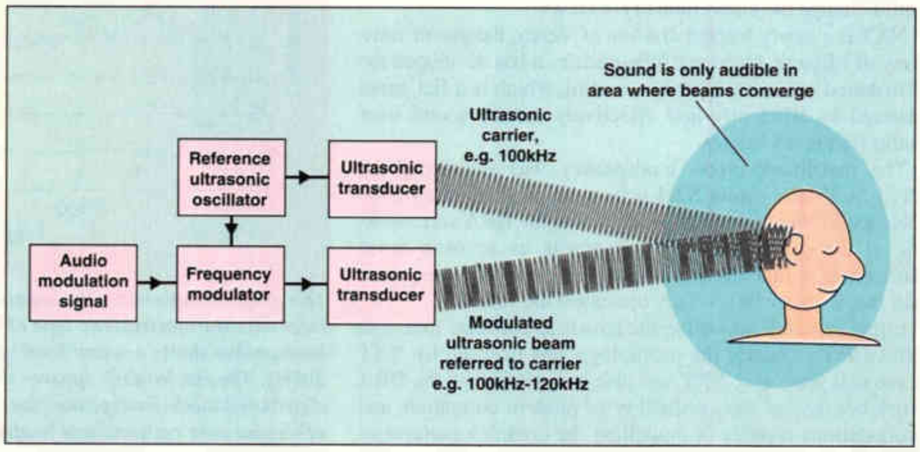
Beat frequencies from two ultrasonic beams crossing can produce audible sound, explains Reg Miles. Could this phenomenon be the basis for a new generation of loudspeakers?

Ultrasonic loudspeakers have been in the news again with the announcement by American Technology Corporation of a prototype system suitable for general audio reproduction.

The sound seems to come from mid-air, rather than the two speakers which are silent. They project beams of highly directional ultrasound, and it is only where the beams cross that audible sound is produced.

The technique relies on the combination tone phenomenon: when two similar frequencies interfere with each other they beat. An additional tone is created that is the difference between the two original frequencies – an effect first noted by the Italian composer Tartini in the 18th century.

In the case of ultrasonic speakers, only the



Acoustic heterodyning, in which two carriers too high to hear produce audible sound where they overlap, allows very low frequencies to be reproduced using small transducers.

a heatsink in high power applications.

The electrodynamic and piezoelectric transducers used to drive distributed-mode loudspeakers have – theoretically at least – a 100 per cent efficiency in converting mechanical energy to acoustic energy says NXT. Practically, up to 98 per cent efficiency has been reached.

In common with conventional speakers however, electrical efficiency is somewhat lower. At best, current magnet technology achieves up to 10% electrical-to-acoustic coupling.

NXT claims the sound from a distributed-mode loudspeaker interacts with boundaries such as ceilings, walls and floors in a completely different manner from conventional units. The sound radiated from a distributed-mode loudspeaker is diffuse and non-coherent. Therefore, boundaries do not cause destructive interference to the same extent as other loudspeakers.

Results from NXT's experiments indicate an almost flat in-room response from the distributed-mode loudspeakers, with only 5dB variation below 1kHz and 2-3dB above. Conventional speakers on the other hand can suffer a loss of up to 25dB at certain frequencies, particularly above 1kHz.

In the domestic environment

Distributed-mode loudspeakers can almost certainly be used in the home. It is worth remembering though that wall mounting the speakers – while saving space and being aesthetically pleasing – will cause a 3dB loss in efficiency from blocking the rear of the speaker.

The diffuse nature of distributed-mode loudspeakers also improve their directivity and spatial coverage. Diffuse radiated acoustic energy is non-directional and, in the main, frequency independent says NXT. Unfortunately, it seems hard to reconcile this claim with that of the sound intensity decreasing as a linear law over distance.

If we accept NXT's claim, then the directivity is in contrast to conventional loudspeakers which have a directional acoustic output that narrows with increasing frequency. If this property can be exploited in products, then it may make it unnecessary for a listener to sit in exactly the right spot for the best quality of sound. Indeed, NXT describe the property as one of the most significant of distributed-mode loudspeaker technology.

NXT claims a whole host of other attributes for the distributed-mode loudspeakers, most of which are subjective. The company claims greater clarity, especially for speech, high spatial quality and better transient response. Little or no perceived distortion and a high degree of linearity compared with older electrostatic flat speakers are said to result from the stiff panels having a small movement. Only time and a few independent tests will bear out these claims.

Flat panels in multi-media

In addition to concert and home speakers, other applications have been suggested for distributed-mode loudspeakers, including multimedia computers and laptops where space is at a premium. Verity describes distributed-mode loudspeaker use in laptops as inevitable in the future.

Other space critical areas are the automotive and aerospace industries. The company has even built a distributed-mode loudspeaker speaker into a polystyrene ceiling tile. In the cinema world, the speaker could double up as the screen. This not only saves space and money, but also means the sound is closely tied to the action.

NXT has built a range of prototypes aimed at specific market areas. It can be assumed there will be some sort of cost/performance tradeoff.

Multimedia and laptop speakers have a response of 200Hz to 12kHz with a sensitivity of 84dB. Tile speakers extend base response down to 100Hz while sensitivity increases to 87dB. For more demanding applications such as home, cinema and concert, the response can be further widened to between 60Hz and 18kHz with 88dB sensitivity.

Verity is to bring out production versions early next year. Although Mission, Quad and Wharfedale all have licences, the company feels licensing of the technology to outside companies is the way forward for real profits. ■

difference is audible. In the ATC system, the beams are produced by a pair of piezoelectric transducers: one is fed a constant 100kHz signal, the other an audio signal that has been upshifted by 100kHz so that it varies over 100-120kHz. It is this 0-20kHz that becomes audible. The speakers link to a hi-fi system via a signal processing box to drive the transducers.

Improved realism

The 'mid-air' effect gives the possibility of moving the sound around a room or cinema. In this way ultrasonic loudspeakers could generate effects that are more realistic than those from conventional surround sound systems. Things could move in all directions, over the heads of an audience, at any speed, given a sufficiently accurate response to directional control signals.

There are other potential advantages in sound being produced externally. Having the frequency response and loudness independent of the size of the speaker means a small device can give a full frequency range that includes a powerful bass.

Hi-fi would no longer be confined to specialised equipment. The only limiting factor would then be the quality of the electronic circuitry. A further advantage of external sound is that the distortions affecting reproduction in conventional speakers are eliminated. Other beneficial uses suggested for these tiny loudspeakers include hearing aids and telephones.

Unhappily, it has also been suggested that the principle has the potential for crowd control. Individuals could be targeted and temporarily disabled by a burst of powerful low frequency sound.

Disabling people was what Matsushita wanted to avoid when the company developed ultrasonic speakers for use at the Tsukuba Science Exposition in Japan in 1985. Their intention was to use the directional qualities to provide localised commentaries. But because it was found necessary to use 140dB of ultrasound to achieve the required volume – a dangerous level – polyurethane filters had to be hung between the people and speakers to selectively absorb the ultrasound. In this case the basic frequency was 40kHz; produced by a matrix of 6600 piezoelectric transducers.

If the ultrasonic loudspeaker is going to be used in large cinemas and for public address systems it is going to be necessary to prove that adequate sound levels can be generated without danger. Doubts have also been cast on whether such high frequencies can travel very far in the air before they are absorbed – which would make the aforementioned academic.

Is nothing new?

Matsushita, and now American Technology Corporation, has received a lot of press coverage for their work on ultrasonic loudspeaker technology – and rightly so; but it is worth remembering that the idea of applying the combination tone phenomenon to loudspeakers came from British inventor Heinz Lipschutz.

His patent of 1978 describes the creation of music and sounds indirectly as a beat-note between two or more inaudible sounds above 40kHz. It goes on to describe how this is achieved using a pair of transducers. Controlling the sound output volume is described, as are the use of units in parallel for directional control and the means of achieving a multi-channel system.

ATC is predicting the first version of the company's design will go on sale in 1997. If it is as effective as the claims made for it, the technology would spell the beginning of the end for the conventional loudspeaker.

The route to pcb cad

In addition to reviewing *Proteus* and *Easy PC,* Rod Cooper presents his five preferences from the ten packages reviewed.

PCB CAD review subjects

This review, which began in the September issue and continues next month, covers the following ten products.

PCB Designer: Niche Software Ltd, tel. UK 01432 355414. £49 inclusive (see September issue).

PIA: AW Software, tel. Germany +49 89 6915352. PIA std 99DM: extended 171DM 32bit 286DM inc tax (see September issue).

Easytrax: Protel International pty, tel. Australia 408 437 7771, UK PDSL, tel. 01892 663298 (see September issue). £6 copying charge.

Ranger2: Seetrax CAE Ltd. 01705 591037, (see October issue) £150 exc £10 p+p and VAT.

Electronics Workbench: Interactive Image Technologies Ltd (Canada), tel. 0014169 775550. UK Robinson Marshall, tel. 01203 233 216, (see October issue) £199 exc p+p and VAT.

CircuitMaker: MicroCode Engineering (USA) UK agent Labvolt, tel 01480 300695. Circuitmaker and Traxmaker cost £199 each excluding vat and p&p, (see November issue).

Quickroute 3.5 Pro+: Quickroute Systems Ltd, fax or phone 0161 449 7101. *Pro* is priced at £249 while *Pro+ is* £399. Smartroute is £149 or £99 supplied with Quickroute (see December issue).

Propak: Labcenter Electronics, tel. 01756 753440, fax 01756 752857, £495 exc VAT (see December issue).

Proteus: Labcenter Electronics, Schematic capture and pcb design, £495 excluding VAT/postage. Windows version and integrated simulation are available.

EasyPC Pro XM: Number One Systems, tel. 01480 461778, fax 01480 494042, £296.69 fully inclusive, or £643 with MultiRouter.

Review 1 – *Proteus*

There is a third alternative to *Propak for Windows* and *Propak for DOS* from Labcenter within this review's price range. That is a reduced-capability version of the company's *Proteus* system, which will be available shortly. I tested a beta version of this system. Called *Proteus Level 2*, it consists of an *Isis/Ares* integrated package as before, but this program is in dos, and it can only handle up to 1000 pins.

Isis, the schematic editor, is 32-bit, so a 386 or better is needed, with a minimum of 2Mbyte of ram. For the autorouter, *Ares III*, a co-processor is required and minimum of a 486DX with 4Mbyte of ram is recommended, although it ran well on a 386 with co-processor and plenty of memory.

The *Isis* part of the system is similar to *Isis* reviewed as part of *Propak* last month, but without such refinements as rounded corners, autosave or on-line help. It has Wiring Autorouter (reviewed last month in *Propak*), though, and an electrical rules check, auto junction dots and many of the other features of *Propak*.

An interesting feature in *Proteus-Isis* is that it is not necessary to click on a menu to open it. The menu opens automatically when the cursor is on it. Considering how many times you have to open menus, this small bit of assistance is welcome.

Drawing quality of the schematics produced in *Proteus* is good as **Fig. 1** shows. This is partly due to it having the same ability as *Propak* to move component label text independently of the component, making it possible to tidy up and compact the diagram. Many of the integration features such as forward/reverse annotation are common to both programs.

Screen layout is immediately recognisable if you have used *Propak* beforehand. The screen drawing area on a 14in monitor is larger at 7.5in by 7in, and the sheet size can be varied from A4 to A0. Multi-sheet schematics are supported in a hierarchy similar to one

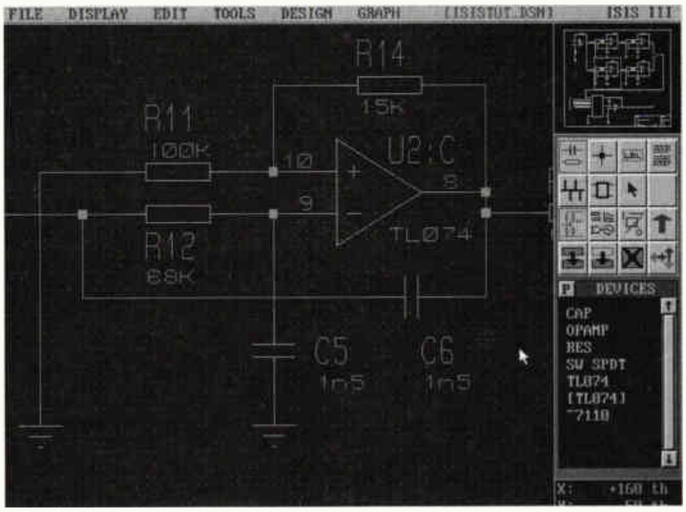


Fig. 1. Typical screen from Isis showing good-quality dos graphics. Note map in top right-hand corner showing what part of the circuit is in view and the permanent parts bin in the bottom right hand segment.

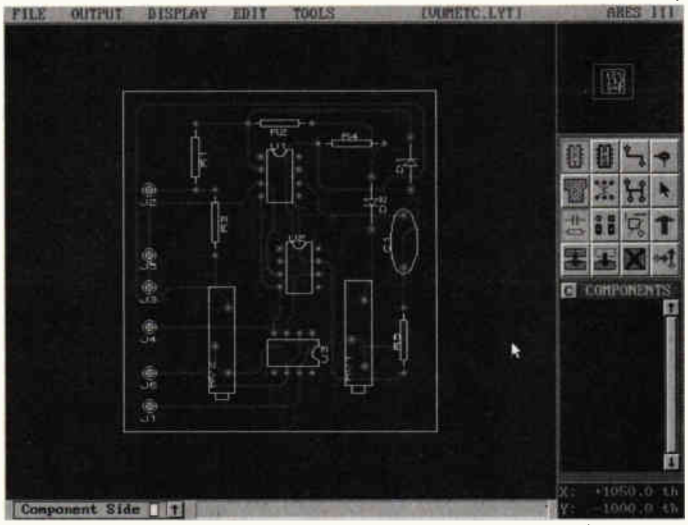


Fig. 2. Results of the Ares autorouter on the test circuit. Compare this routeing with the other four rip-up-and-retry autorouters.

described in *Propak*. The speed of screen redraws is noticeably quicker for a given hardware set-up and if you are using a slow pc this aspect may be significant.

Component libraries in *Proteus* are different from *Propak*'s in that there are longer lists of specific discrete types. For many of the items listed, component pcb information is included when the schematic symbol is picked. The libraries are in the same style as *Propak*, and include a picture of the selected part – a useful feature rarely found in dos programs.

With *Proteus*, it is necessary to select component outlines for a few non-specific items like resistors and capacitors, assuming you don't want the default outline. However, Labcenter's ADI system is still available for speeding this up. The most important difference is that the pcb part of *Proteus*, called *Ares III*, has a re-entrant, gridded rip-up-and-retry autorouter. The standard autorouter already reviewed is pretty good, but this is better, and it could route the test board 100% without any concessions, putting it in category A. Pre-run configuration of this autorouter provides good flexibility. Like the *Propak* autorouter, this one can be configured to autoneck and can route off-grid.

Transferring from *Isis* to *Ares III* is simple, involving just one click. The same two manual drawing options of routing from scratch or from a rat's nest are available as in *Propak*. Note that the excellent rat's-nest/interactive drawing method is practically identical.

One other interesting feature in *Ares III* is that components can be placed at any angle, other than the usual 90° choices. Boards with non-orthogonal placements look untidy, but this feature can get you out of awkward corners with difficult or odd-shaped components. Designers of surface-mount boards may be interested in the linear resolution of 10nm offered by *AresIII*.

If you intend to use a plotter for artwork generation, the dos drivers of *Proteus* may be preferable.

Another noteworthy difference between *Propak* and *Proteus* is that *Proteus* is intended as combined schematic/pcb/simulation package. A matching simulation program for *Propak*, called *Lisa*, is available at £495, or rather less if you buy the combined package.

Lisa is not fully reviewed here as the combined price puts it well outside the arbitrary review budget of about £500. Also, there are no working samplers in the standard package.

Many of the comments already made regarding learning curves etc, apply to *Lisa*. However, if you have learned how to operate *Isis*, you are already halfway towards operating *Lisa*. As the whole program is integrated, it is just as easy as *Circuitmaker* or *Electronics Workbench* to step from schematic capture into simulation. The usual analogue and digital simulations and a type of mixed-mode simulation are included. There is also noise analysis, but there are no input/output impedance plots or analysis of circuit board effects.

Besides the free demonstration disks for *Proteus*, there is an evaluation kit at £40 with a 150-pin limit and no print-out capability, except for samples. It includes the full manual and its cost can be recovered when you buy the full product.

Summary

Being sophisticated, *Proteus Level 2* has a comparatively steep learning curve and many features, so will mainly appeal to regular users.

If you want a rip-up-and retry autorouter, this system may be preferable to *Propak*. The *Proteus* autorouter can be expected to give better completion rates than *Propak*'s on the more difficult boards.

I would disregard the fact that *Proteus* runs under dos. The product is sufficiently well-designed that the benefit – if any – of transferring to Windows is small. If you have a slower 386 or 486 the program runs at a more acceptable pace than Windows programs.

Availability of a integrated simulator in the same operating style is a big plus and I think most designers will find the libraries more user-friendly than *Propak*'s. The 1000-pin limit confines it to medium-sized boards or less, so it would be necessary to check if you ever go over this limit.

There is an even smaller version of this program called *Proteus level 1*, with a pin limit of 500 pins and the standard autorouter at £250.

Review 2 – *Easy PC*

Easy-PC Professional XM is a dos-based schematic drawing and capture program, combined with manual pcb layout, running on a 386DX minimum, with at least 4Mb of ram.

For a dos program, it is remarkably large at 6Mbytes, but this may be explained by the fact that it acts as the central manager for various simulation programs and an autorouter, which are optional extras. It also has working sample versions of the simulation programs, which add bulk.

Easy-PC Pro XM will not work without a mouse or digitising pad. Also, a disk cache program is almost essential. In theory, it is possible to run 32-bit programs like this on a 386SX. But when I attempted it the results were not satisfactory, even with a co-processor and 16Mbyte ram. The program ran, but it was hesitant, and would occasionally hang.

This package is menu-driven with no on-line help, so you have to read the manual. All the manuals are comprehensive, and although they attempt the difficult task of balancing the needs of both beginners and those familiar with cad I think the tendency is towards the latter.

The *Pro XM* manual starts with pcb layout and then covers schematic drawing. This seems an odd choice; in an integrated system you would expect the sequence to be the other way round. Moreover, schematic drawing is only covered as part of a chapter on connectivity – a third of the way through the book. The program has a good number of features and has a comparatively steep learning curve to suit. Methods of performing some functions are noticeably different from its competitors.

There is no mention of net-list links to or from third party programs in the *Pro XM* manual. It seems that Number One Systems' philosophy is to provide everything required in one system – schematic drawing and capture, simulation, and pcb layout. In this respect the company currently holds a commanding position in this sector of the market. Although other programs in this review offer connection to simulation via net-list output, or schematic capture integrated with simulation, none of them offer such a complete and thoroughly integrated system.

Starting with schematic drawing, on selecting a fresh sheet in the schematic section, you are presented with the usual dot-grid rectangle. The drawing area is $32in^2$, with no support for multi-sheet schematics. On a 14in monitor you see about 9.5-by-6.5in – one of the best available drawing areas.

Zooming is activated by pressing 'Z' on the keyboard, pointing the mouse pointer at the desired centre of zoom. Similarly, you can unzoom by pressing 'U' and pan by pressing 'P'.

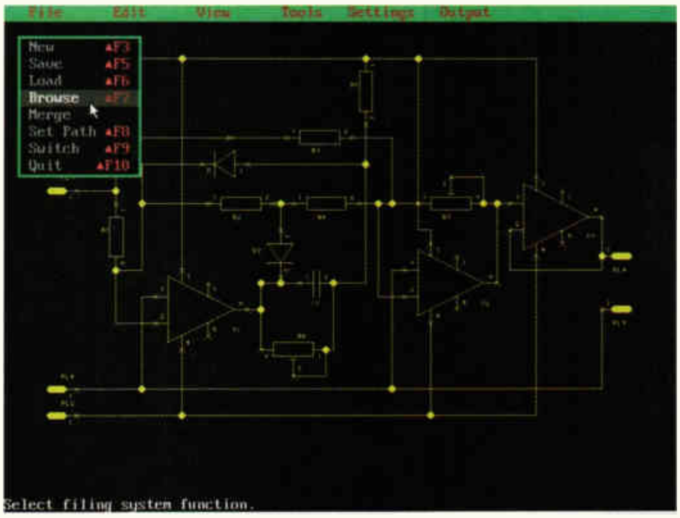


Fig. 3. Typical schematic in EasyPC, showing one of the drop-down menus. Note 'X' connections on devices.

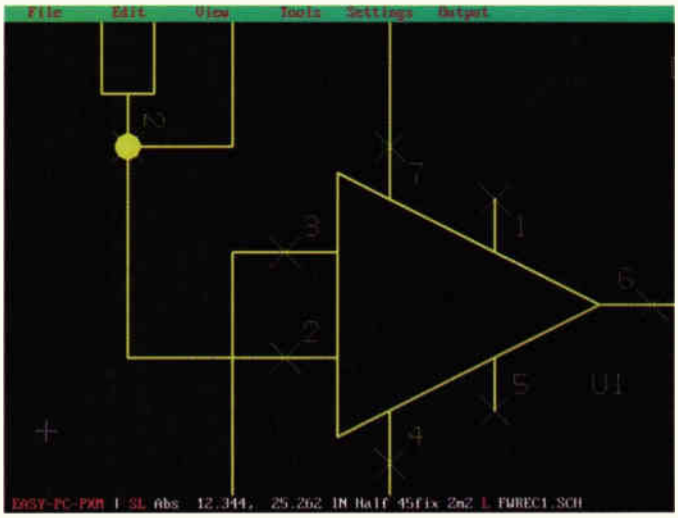


Fig. 4. Enlarged view of schematic illustrating graphics quality.

Alternative methods, such as using the numeric keys, are provided but I found this method so logical and easy that I stuck with it. The same method applies to pcb layout.

The basic library provided in package is well balanced and adequate for general usage. There are also optional, more comprehensive libraries, for example, smd, analogue devices, and the *74HC/74HCT* series chips. However, if you want these libraries to be matched in the simulation packages, further libraries modelling the extra components also have to purchased. At £48 + VAT per library, this could work out to be expensive. Even so, compared to high-end packages the overall cost is still value for money.

Component placing is done by selecting 'new component' from the menu and then pointing the mouse to where you want the component to appear. You then choose 'browse', whereupon you are given a set of library volumes.

Clicking on a volume in any library gives you the components in brief text form. For information on the symbol, such as its pcb outline, the literature has to be consulted. Picking a specific component with the mouse draws it on the drawing area in the pre-allocated position. If you do not increase the zoom factor, the component is likely to appear as a small dot.

This method of selecting the component position before selecting the component differs from that used in other programs. At first I found the technique awkward, but soon became used to it.

There is no parts bin, so to get another component you have to repeat the process, making the method slow. You could speed things up by copying single components that are already on the screen, but the manual warns against copying blocks of components if you intend to use schematic capture. Similar methods are used to put the tracks on the sheet.

To move components, you simply select 'edit component' then pick the component. There is no 'move' command; the software assumes you want to move the component.

Selecting a new position with the mouse makes the component jump to the new position – even if its across the other side of the screen. This is also different from the technique used in other programs, where the moving component trails along with the mouse pointer. I strongly suggest you try out both techniques from the appropriate programs on evaluation disks to see which method suits you.

To learn these variations takes some time, and they are easily forgotten. I think it is fair to say the system is not all that intuitive, compared to other programs in the review. On the

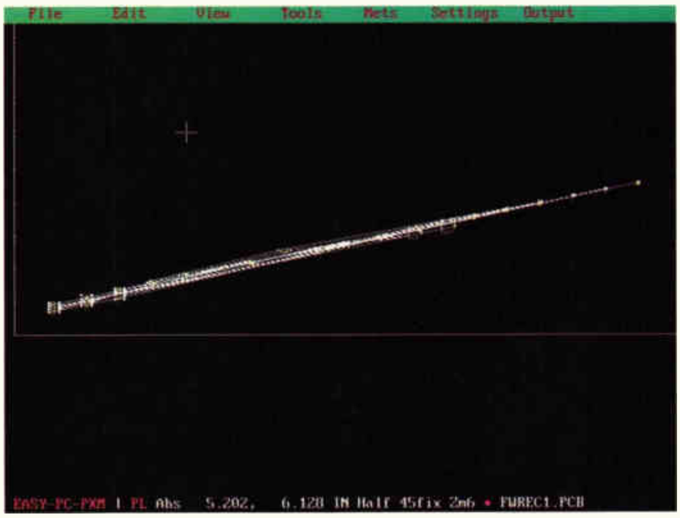


Fig. 5. Linear type rat's nest array first produced from schematic, Fig. 3.

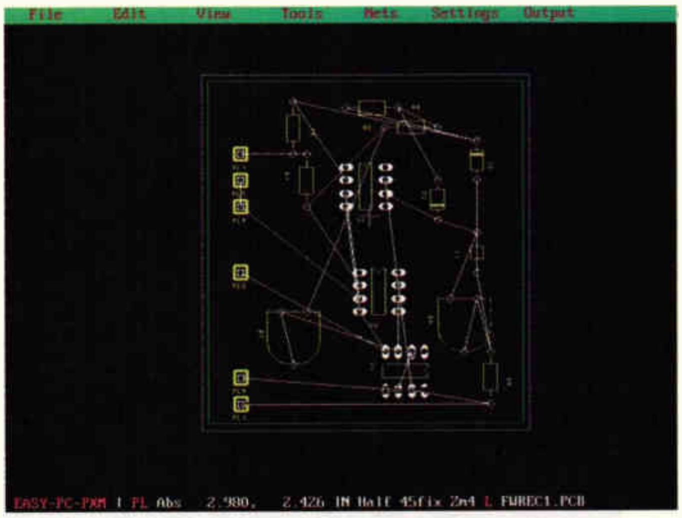


Fig. 6. Rat's nest produced from the linear array of Fig. 5. To reach this stage from the linear array is time consuming.

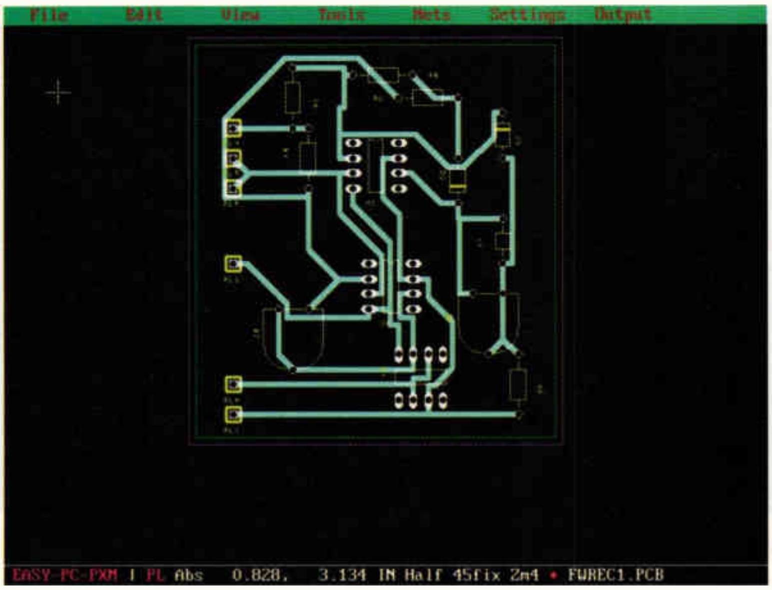


Fig. 7. Results of using Easy pc's MultiRouter autorouter on the rat's nest of Fig. 6.

Autorouter comparisons

Explained in full in the October issue, this categorisation gives you an idea of which autorouters perform best.

Category A – able to complete the test circuit (relative time taken in brackets).

Spectra (2)	from	Ranger 2
MultiRouter (2)	from	Easy-PC
386 Rip-up (10)	from	Ranger2
ARESIII (2)	from	Proteus
AR3 (5)	from	Quickroute 3.5

Category B – able to complete the test circuit with slight relaxation of design rules.

Ares (2)	from	Propak

Category C – unable to route the test circuit completely.

Range2 Standard (1)
Traxmaker (1)
Quickroute 3.5 Standard (3)

Category D – unsuitable for use with the test circuit.

P.I.A
EasyTrax

other hand, the same techniques are used over again in the pcb layout and to some extent in the simulations.

If you want to rotate or flip a component, you have to select these commands from a drop-down menu. Any component text moves and rotates with the component, but the text is fully editable so the schematic can be subsequently made to look neat and tidy.

Placing and editing the rest of the drawing items, such as connectors and labels, follows a similar procedure. Other features of the schematic part of the program are that components are automatically annotated; pads remain connected during any component manoeuvre; drawing can be orthogonal using a device called 'angle fix', which can also force a 45° angle of drawing and, unusually, curved lines can be drawn.

There is also a feature of confirming connectivity during drawing, in the form of an audible 'bleep' when a correct connection is made. This is not as good as inhibiting bad connections, but better than nothing.

There is no map showing where you are on the drawing sheet, but on the other hand it was not as easy to lose the drawing off-screen as with some programs because the panning method gives good control. Un-zooming reveals where any lost drawing is.

Easy-PC Pro XM does not have autosave. Instead, a 'bleep' and a screen message requests a manual save at regular intervals. After an hour or so, repeatedly having to manual-save becomes tedious, and it is tempting to skip saving.

Converting the schematic to a pcb was very easy. Using just one command, the components are dumped as a rat's nest in a linear array in small scale on the screen, and the first step is to zoom in on them.

Manoeuvring components in the rat's nest is easy once you have mastered schematic drawing, but it is time-consuming. A linear rat's-nest dump is not as easy to sort out as the system used in *Propak* or *Ranger2*. Some assistance is given in the form of a net optimiser function. This rearranges the rat lines to their shortest route. After arranging the rat's nest, you could manually route the board by rubber-banding the rat lines, or you could go on to use the autorouter. The autorouter is a separate package, so is reviewed on its own.

Pro XM also has a manual drawing package. It is similar in use to the schematic drawing program, and the results are comparable to the other manual drawing programs reviewed.

Number One Systems' new autorouter, called *MultiRouter*, integrates with *Pro XM* schematic capture. It cannot operate in stand-alone mode and needs *Pro XM* with a revision number of N0605 or later in order to work. The version I used for the review, which has the added capability to route single-sided boards, needs revision N0629 or later.

Although this is the company's first autorouter it is a very competent product. It is 32-bit software, configurable, re-entrant two-layer router, with rip-up-and-retry, push and shove. It also has autoneck (called track fattening here, but in fact a very similar technique) and many other features.

This autorouter can readily route double-sided boards to 100%, given a reasonable rat's nest, and routed the single-sided test circuit, putting it in category A. Hardware requirements are a 386DX with 8MB of ram and 20Mbyte hard disk space. A co-processor and SmartDrive help.

MultiRouter is a grid-type router with adjustable grid spacing, but it always routes off-grid to difficult components. This provides a good compromise between the grid-bound and grid-less types of autorouter. Getting from *Easy-PC* to *MultiRouter* is easy; just a click in the tools menu starts the program and you would not realise you were transferring to an optional add-on package.

There is not a lot of pre-run configuration to be done but sufficient to give good versatility, and I think it strikes about the right balance between being too complex and too simple.

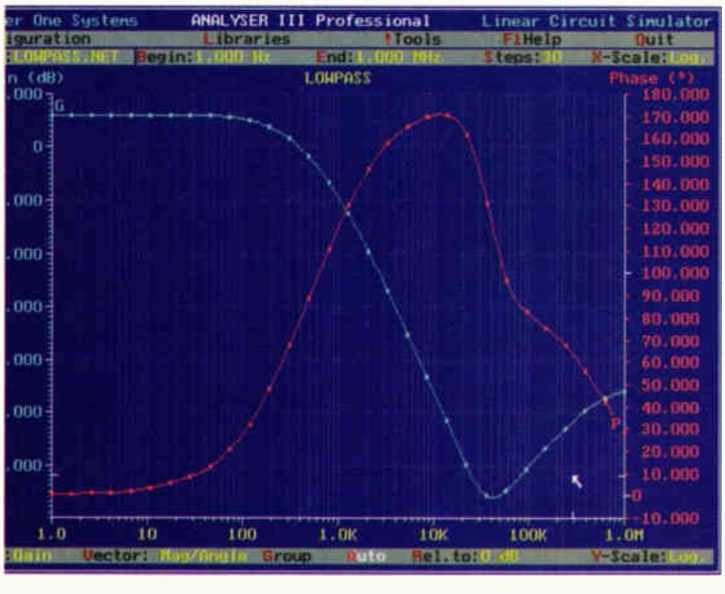


Fig. 8. Illustration of where Analyser III scores over other simulators – a plot of input impedance of a low-pass filter. A similar plot is easily obtained for output impedance.

Being re-entrant, *MultiRouter* can be used in conjunction with manual routing. You can rubber-band a few rat lines first, as you would, say, with the thick buses on a pcb for a psu. The router then intelligently uses these to make further connections without ripping them up.

Summary

Combined with the *MultiRouter* option, *Easy-PC Professional XM* is clearly a competent package. With its fairly steep learning curve it would suit frequent users. In my view, occasional users would have difficulty remembering how to operate the system as it stands.

I would like to see some functions made automatic, such as autosave and the net optimiser, and a parts tray added to speed up schematic drawing. However, these are minor points in a program provided with most of the important features designers need, and capable of giving good and reliable results. *MultiRouter* is one of the better autorouters of the review and is easy to configure and run.

What might clinch the purchase of this system for many professional designers is the availability of the integrated simulation programs at prices which are modest, compared to others on the market of similar capability. Referring to the complete system, the makers say that the whole is more than just the sum of the parts, which I think neatly sums it up.

The other outstanding advantage of the simulation part of the system – especially for designers in the radio-frequency field – is the integration of the analogue analyser with the electromagnetic analyser to account for effects introduced by the pcb itself – a simulation *tour de force*. ■

Round up

Starting in the September issue, this review has shown that basic features in all the ten packages investigated varied widely. For example, taking just one parameter, available screen drawing area on the 14in monitor taken as the base standard varied from a miserly 45 square inches to a more usable 62.

No one program in this review can be singled out as the best. Although several were were proficient in many respects, each program had a shortcoming of one sort or another, being too difficult to learn, too laborious to operate, short on features, or limited in interaction with other useful programs like simulators.

By now, you will have gathered that the perfect pcb cad package for all tasks does not exist at this level, although a few come close to it. The perfect package for a specific need does not exist either. If it did, it would have the intuitiveness of *PIA*, the schematic drawing of *Isis*, the graphical libraries of *Quickroute*, the rat's nest system of *Ranger2*, the integrated simulators of both *Easy PC* and *CircuitMaker*, yet would only cost £200.

The task of allocating recommendations for the programs reviewed above is a difficult one because they all had some aspect in which they excelled. In any case it should be obvious which program suits you from reading the review – perhaps between the lines from time to time – and trying the evaluation disk, so just a brief list of recommendations is given below, based on the 'horses-for-courses' principle.

Value for money

Best value for money is undoubtedly *Ranger2*. For only £150 you get a complete integrated cad system with a moderately able double-side autorouter which will work on almost any pc. You will not become quickly frustrated by lack of some feature or other that in the future you find you want.

Ranger2 is generously featured and sophisticated. It has an acceptable learning curve, and once learnt, operation is easy. This package has the added advantage that if you like it but want a more competent autorouter, you can add the more powerful 386 rip-up autorouter for only £50. By spending rather more, you can easily up-grade to the redoubtable Cooper & Chyan autorouter. Not many firms offer such a choice.

Superior schematics

The recommended system for producing superior schematic drawings, and for manually routing a board from schematic capture, is *Propak*. The computer assistance for this type of routing is very good. *Isis* schematic drawing is good enough for desk-top publishing. The package also has net-list export to a simulator, and an above-average autorouter.

You may prefer *Proteus Level 2* in this category if you want a more powerful autorouter than *Propak*'s, as well as good schematic-manual routing and integrated simulators. But note the size limit of 1000 pins.

For re-entrant use, that is, a mixture of manual routing and autorouteing, *Proteus* is particularly good with its rip-up-and-retry autorouter. I recommend this system for routing boards such as those single-sided pcbs or special-purpose pcbs, surface mount for example, that are unlikely to be completed successfully by autorouter alone.

Comprehensive features

If you must have truly comprehensive simulation combined with an integrated schematic capture and a rip-up-and-retry autorouter, then Number One Systems' *Easy-PC Professional XM* combined with *MultiRouter* is in a league of its own.

The cost of *Easy-PC* combined with *MultiRouter* is on the edge of the budget for this review, and note that the simulations and extra libraries take it well over the budget limit. This package has a steeper learning curve and is not as user-friendly as either *CircuitMaker* or *Electronics Workbench*.

In fact, *CircuitMaker* emerges as the system with the most potential for being the best all-round low-cost schematic capture/simulator/pcb package. With its intuitive, graphical interface, gentle learning curve, big library, numerous useful features, easy schematic drawing, and reasonable price, it comes very close to being the best well-balanced all-round budget package.

Circuitmaker however misses the target at present because the basic simulations are not as wide as *Easy-PC Pro XM*, and the autorouter is in category C. With some improvement of the analogue simulator and a better Windows-based autorouter instead of the present dos-based one, it could become a truly formidable system. This may surprise some designers because *CircuitMaker* is essentially a simulation product, albeit coupled to a pcb program, but the maker appears to have a robust approach towards enabling the package to do pcb design.

PCBs by computer – the future

It is clear that a system to do just pcb artwork from a schematic does not fully realise the benefits of schematic capture. If schematic capture is already provided to run an autorouter, then it makes sense to run an integrated simulator from it as well, and *vice versa*. You can of course link up with a third-party simulator or autorouter on some programs, but you then have re-learn another programmer's method of operation – which is completely against the concept of user-friendliness.

The product that offers all three in one integrated package has a distinct advantage over those that do not. In this context, to make the best of the present chaotic situation, there is a crying need for a net-list converter program. This would take one maker's net list and convert it into any of the dozen or so in current use. Programmers please note.

Secondly, what has emerged recently in computer-aided design is the easy graphical user interface which makes some programs almost pleasant to operate. I suspect that programs that stay with difficult concepts and still demand undue mental effort or manual dexterity will fade away even though they do give good results.

The dark days of a special priesthood grappling with obtuse commands and typing in cryptic net lists for hours just to get something to work are nearly over. Now, any electronic designer with a pc can get to grips with pcb-cad – given the right software choice.

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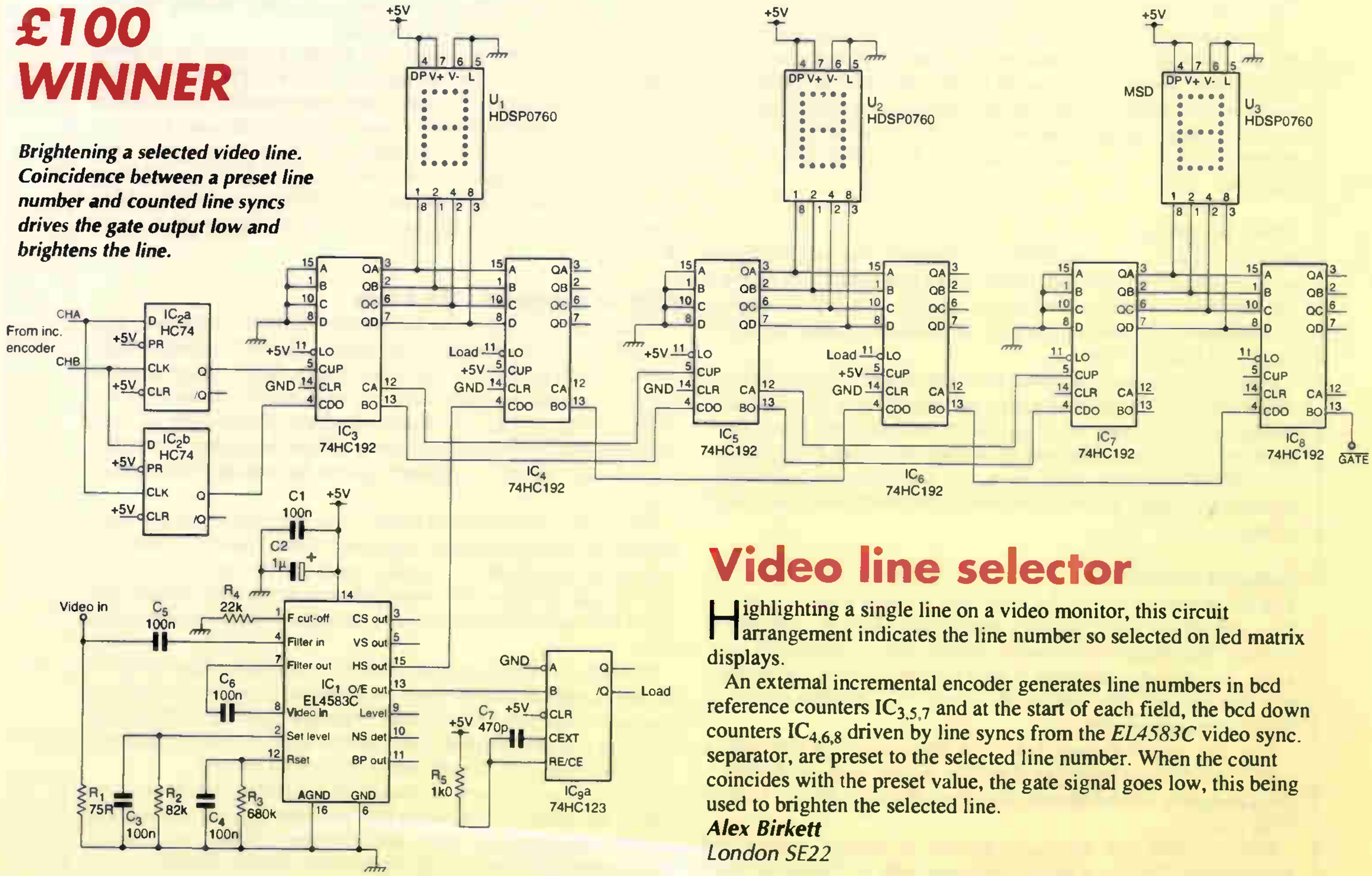


Video line selector

Highlighting a single line on a video monitor, this circuit arrangement indicates the line number so selected on led matrix displays.

An external incremental encoder generates line numbers in bcd reference counters $IC_{3,5,7}$ and at the start of each field, the bcd down counters $IC_{4,6,8}$ driven by line syncs from the *EL4583C* video sync. separator, are preset to the selected line number. When the count coincides with the preset value, the gate signal goes low, this being used to brighten the selected line.

Alex Birkett
London SE22

Simpler thd meter

Although based on the design by Hickman[1], this variant employs fewer components.

Values shown are normalised to ω=1; the curve was obtained using these values. I based calculations on a unity gain at ω=2 and ω=3.

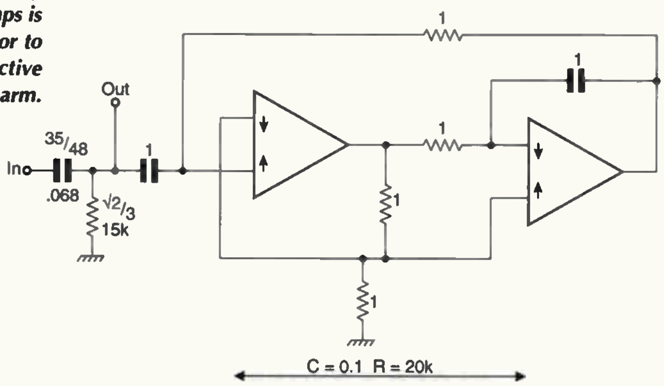
Most of the circuit appears as inductance to earth; other methods of doing this exist, but this one does not need critical components. An obvious disadvantage of the circuit is its fixed frequency.

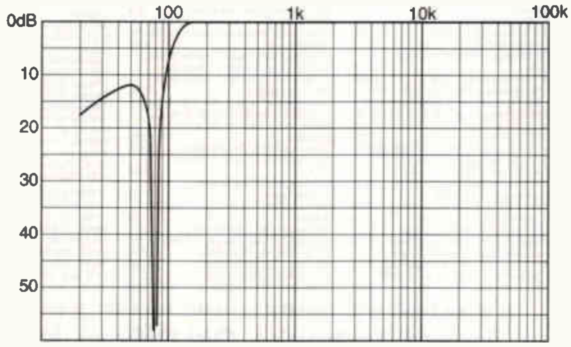
McKenny W Egerton
Owings Mills
Maryland
USA

Reference

1. Hickman, Ian. High-performance thd meter. *Electronics World + Wireless World*, January 1996, p52.

Front end for a thd meter, which produces the response shown. Circuitry around the op-amps is effectively a gyrator to simulate the inductive arm.





Two-pole, differential active filter

Converting a two-pole filter of the standard form into a type with differential input and output or differential. in/single out is a logical procedure.

Figure 1 is the standard, single-ended form, which converts to fully differential form by simply mirroring the circuit, as in **Fig. 2**, where $C_{1,1a}$ can be combined.

Since the network itself appears as a balanced bridge to common-mode signals when seen from the amplifier inputs, and since the amplifier outputs will accept common-mode voltages, an arbitrary common-mode voltage can be applied to either or both input and output pairs of terminals. This means that the balanced inputs and outputs of the Fig. 2 circuit may be balanced and single-ended respectively, as in **Fig. 3**.

Component values may be calculated using standard design procedure[1].

John D Yewen
Leighton Buzzard, Bedfordshire

Reference

1. For example, Chen, Carson, *Active Filter Design*.

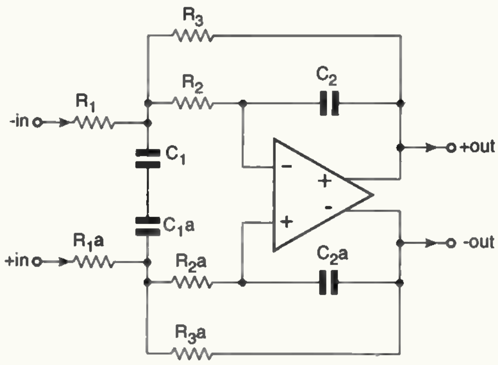


Fig.2. Fully balanced version of Fig.1 obtained by simply doubling up.

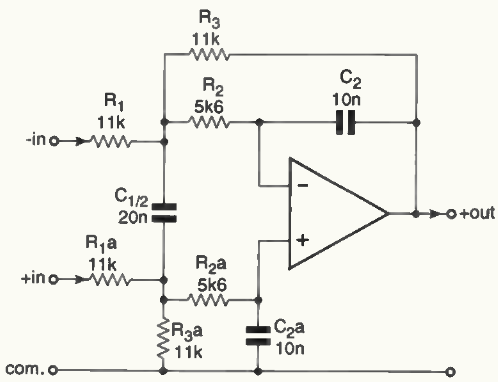


Fig.3. Differential-in/single-out allowed because of common-mode behaviour of network.

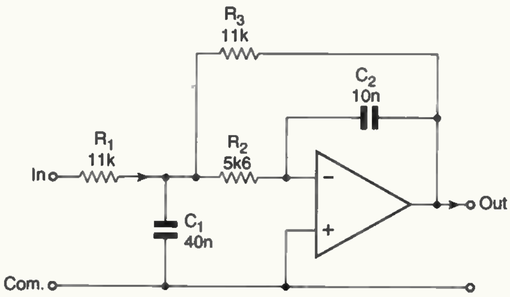
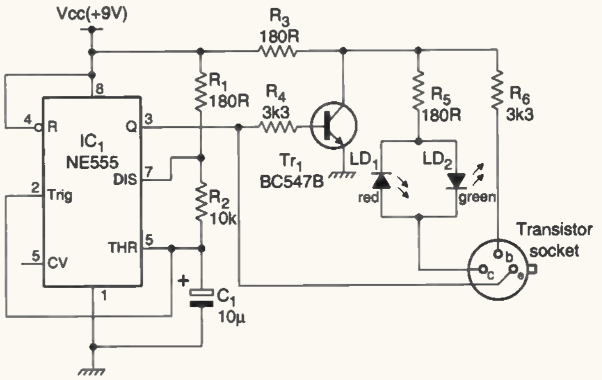


Fig.1. Standard, single-ended, two-pole active filter.

Go/no-go transistor and diode tester

This is a simple device to indicate the basic health or sickness of transistors and diodes and also to show their polarity.



A 555, connected as an astable multivibrator, drives Tr_1 with a square wave, the device under test thereby having the same signal applied to its base and collector and an antiphase one to its emitter; both n-p-n and p-n-p types can now be tested.

With a component in the socket, current flows into or out of the collector and flashes led 1 for p-n-p and led 2 for n-p-n devices. If neither flashes, there is an open circuit; if both flash alternately, a short.

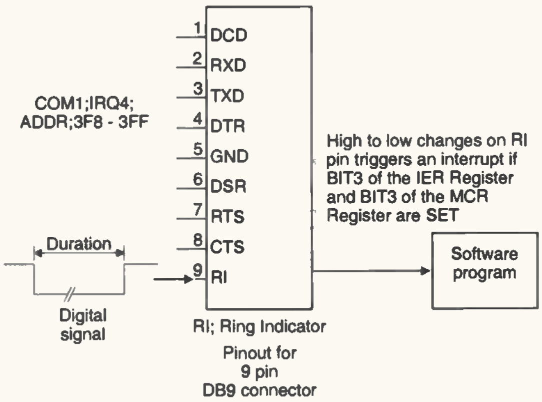
Connect diodes to emitter and base terminals, any way round. One of the leds will flash for a working diode, both for a short and neither for open circuit.

Darko Skokic
Krizevci
Croatia

Tester indicates whether your transistor or diode is still alive and if so, which polarity it is.

Precise timing via the pc's RS-232 port

An RS-232C port and very little external circuitry allows the timing of external events – in the original, the 'time-of-flight' of an ultrasonic pulse. Depending on the computer used, time/count can be about 1µs.



Simple method of providing event timing, using the Ring Indicator line of an RS-232C port and not much else.

External hardware is merely required to provide a low signal for the duration of the event being measured, a set/reset flip-flop in my application, the output of which being taken to the Ring Indicator of the Com port, pin 9 of the 9-pin port connector. As the RI line goes from high to low, it generates an interrupt, which triggers a software routine to count in a loop until the RI line again goes high, all other interrupts except the keyboard being suppressed. Interrupt-driven software speeds up system response to external events.

Calibrate time/count by feeding the output of a square-wave generator at a known frequency to the RI line. A 50MHz 486SL laptop gave 1.9µs/count, the use of assembler code in the interrupt handling procedure improving this to 1.697µs/count. A 75MHz Pentium laptop gave 1.1µs/count.

Richard Weir
Northwestern University Medical School
Chicago
USA

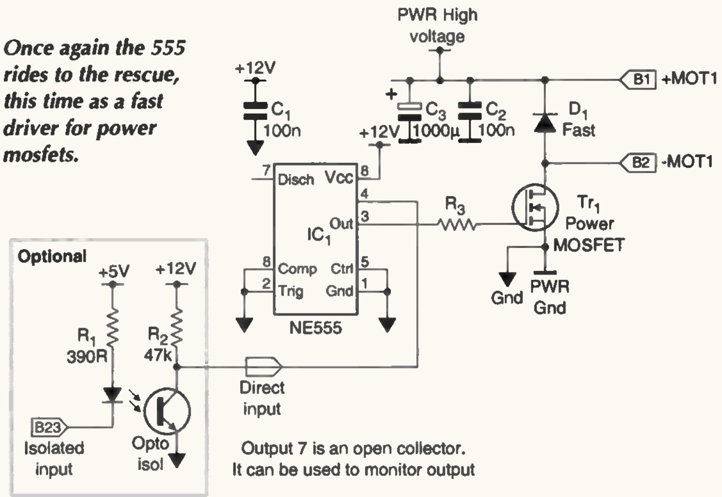
555 drives power mosfets

Parasitic gate capacitance in a power mosfet detracts to some extent from the image these devices possess of being easy to drive. To reduce switching losses, switching time should be around 100ns, which requires the handling of currents of hundreds of milliamps. There are special ic gate drivers, some of which are somewhat fragile and others more than somewhat expensive. The 555 timer ic is neither and provides a solution, yet again.

555s have a robust output buffer, switching at under 100ns and make a good, cheap gate driver, as shown in the circuit diagram. Operating frequency is 0-100kHz; output turn-on delay is 0.25µs and turn-off delay 1µs; rise and fall 60ns with a load such as 50A mosfet. I developed the circuit for the dc controller of a light electric vehicle.

Dominic Bergogne
Saint-Etienne
France

Once again the 555 rides to the rescue, this time as a fast driver for power mosfets.



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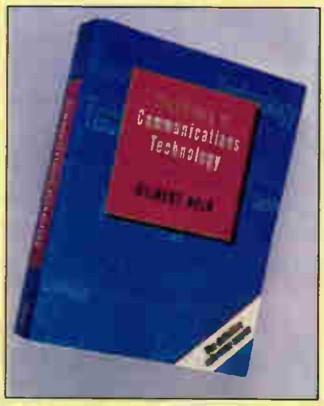

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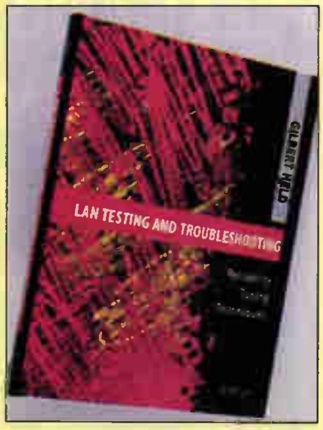

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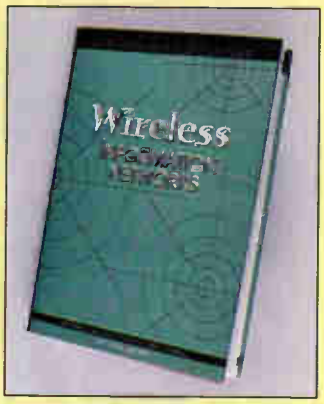

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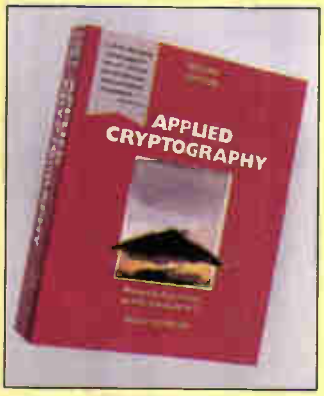

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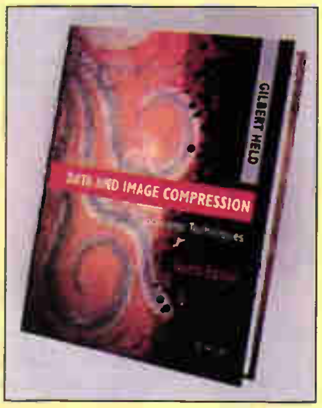

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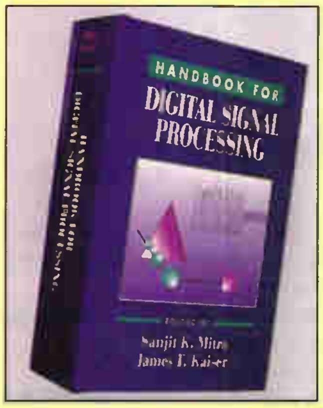

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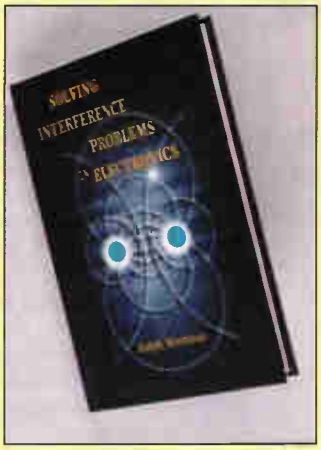

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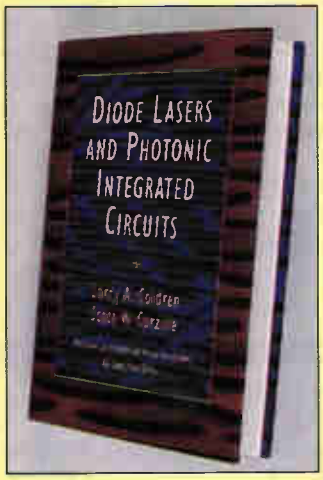

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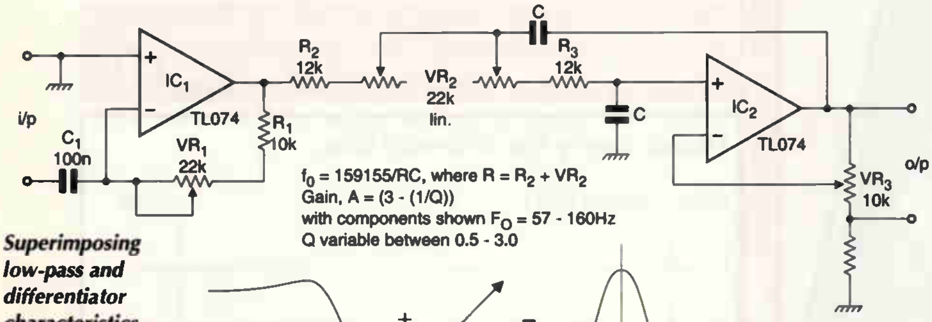
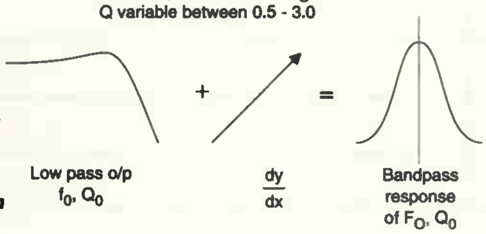




Superimposing low-pass and differentiator characteristics produces a band-pass response, in a circuit that is amenable to independent variation of frequency and Q.

If you increase the gain of a second-order low-pass filter by 6dB/octave, the result is a band-pass filter, as the diagram shows. This obvious but elegant procedure enables the design of a variable-frequency band-pass filter which also has variable Q.

Frequency and Q of the low-pass filter around IC_2 are easily and independently varied by VR_2 and VR_3, which means that the pass band is variable over several octaves and, with the components shown, Q varies in the 0.5-3 range. Gain of the op-amp must be at least $20\times Q^2$ at the centre frequency.

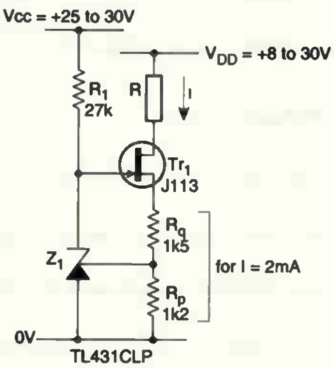
Increasing gain with frequency due to the action of the differentiator is countered by VR_1.

The prototype circuit works well as a speaker equaliser.

Jeff Macaulay
Chichester, Sussex

Programmable current source

Although constant-current diodes such as the *J500* series are simple to use, they cannot be adjusted and drift with temperature. The circuit shown here uses a *TL431CLP* adjustable shunt regulator to allow variation in the range 50μA-5mA to be determined by the value of R_p, which may be a variable resistor, if required.



Current source is variable from 50μA to 5mA. May be used to give a floating reference voltage, where R is a resistor whose top end is connected to an 'unknown' potential V_{dd}. Then $V_{ref}=-2.5(R/R_p)$ with respect to V_{dd}.

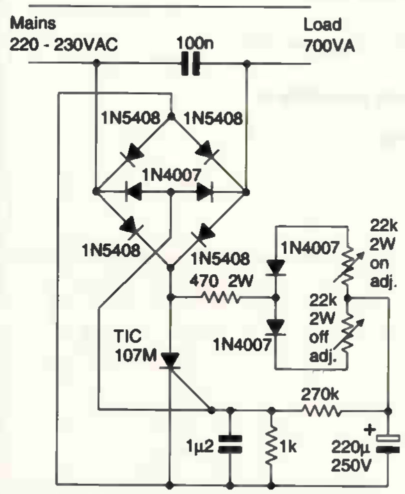
Output current is given by $I=E/R_p$, E being the reference voltage of the regulator: typically 2.5V to within 2% and having a temperature coefficient of 50ppm/°C. Coupling to the j-fet provides a very high output impedance: 100MΩ at 2mA and 4.7kΩ load switched from 20V to 30V.

Rejection of supply variations is around 85dB at 100Hz in the circuit as shown, maintaining this performance up to about 25kHz; for even better rejection, split R_1 and decouple the common point.

To avoid the need to scale R_q/R_p in the ratio $^5/_4$ when varying output current, replace R_q by a small 3.3V zener.

C J D Catto
Cambridge

Repetitive zero-crossing ac switch



Having an on period adjustable from 0.3s to 4s and an off period between 0.2s and 10s, this switch controls a resistive or inductive load of up to 700VA.

Scr *TIC 107M* switches at the mains zero point, since the two diodes keep the gate at cathode potential except during a short period around zero crossing. A delay determined by the 1.2μF capacitor puts the switching point more or less in the middle of this period, although the analogue nature of the circuit makes absolute accuracy difficult to achieve.

When the scr gate voltage reaches its trigger voltage as the electrolytic charges, the scr conducts and will remain in conduction while there is enough sustaining current as the capacitor discharges. The scr shown was chosen for its sensitive gate characteristic to avoid the need for a large capacitor. The 0.1μF capacitor bypasses spikes from either supply or load.

Frequency is reasonably stable, but is slightly affected by temperature and supply voltage.

D Di Mario
Milan
Italy

Inductive ac loads such as motors and solenoids up to 700VA can be controlled by this zero-crossing switch, which can be adjusted in frequency and on/off times.

Measuring speaker cables

Loudspeaker wiring may well cause an audible deterioration of sound quality, but if Cyril Bateman's new measurements are indicating performance, some specialist cable manufacturers appear not to have a full understanding of the problem.

I demonstrated last month that loudspeaker cable impedance is important in determining combined amplifier/loudspeaker damping performance.[1] This demonstration involved measurements using two cables that were identical apart from their characteristic impedance.

Further experiments have helped quantify the effects of cable characteristics, by frequency, cable dc resistance and cable impedance. To allow for the differing transit speeds and closed-loop output impedances of mosfet and bipolar output devices, all measurements were duplicated using a Maplin *LP56L* mosfet amplifier and Douglas Self's 50W Class B design.[2]

My experiments were to complete the turn-off transient tests of the first article by measuring a variety of cables at several frequencies. This was carried out using the resonance test set-up previously described[1] and frequencies of 159Hz, 1592Hz, 10kHz and 21.1kHz, requiring change of resonating *C*s and *L*s.

Using four-terminal bridge measurement methods, the parametric values of the cables were quantified and finally, the cables' attenuation with frequency was measured using the loss test set-up.

Table 1. Resonant circuit speaker damping results using Maplin and Self test amplifiers. Measurements were made using the resonance test set-up and a Pico ADC100 virtual oscilloscope. Due to variations in resonant circuit Q with change of frequency and drive level at 21.1kHz, results could not be plotted. Results are instead ranked in order of amplifier/cable performance, with 1 offering best damping, 12 the worst.

Cable under test	159Hz Self	159Hz Maplin	1592Hz Self	1592Hz Maplin	10kHz Self	10kHz Maplin	21k1Hz Self	21k1Hz Maplin	Overall rating
Coax styles									
75Ω Cat. 500	10	8	8	8	8	8	7	8	8
75Ω CT100	7	7	7	7	6	7	6	5	7
50Ω RG58C/U	11	11	11	11	10	9	8	7	10
50Ω URM67	3	1	1	1	3	3	3	4	3
3mm Mark 1	2	2	3	2	2	2	1	1	2
3mm Mark2	1	2	2	3	1	1	1	2	1
Fig. 8 styles									
2192Y bell wire	12	12	12	12	11	12	11	11	12
42 strand	9	9	9	10	8	10	10	10	9
42 strand modified	8	9	9	9	12	11	12	12	11
79 strand	4	4	4	4	7	6	8	9	6
2mm twin special	6	6	6	6	5	5	5	6	5
Supra Ply 2.0	4	5	5	5	4	4	4	3	4

Resonant circuit results

As the measurements progressed, two problems emerged. To reduce the numbers of inductors needed, the *L/C* ratio was changed with consequent Q change with frequency.

Rather more serious however, at the highest frequencies the drive and measurement levels used had to be reduced

Making cable measurements

When measuring low impedances, such as the dc resistance or the inductance of these test cables, it is essential to use the best four-terminal measurement practices.

For dc resistance, this is easily applied. Simply pass a known current through the cable using two current leads, then monitor the voltage drop using a dvm with separate leads. In this way contact resistances and test lead resistances are removed from the measured result.

Long ago I standardised on a stabilised test constant current of 1A supplied by a simple *LM317T* based constant current circuit.

Measurement of cable inductance – especially at audio frequencies – is more difficult. Satisfactory results require a suitable four-terminal impedance bridge to allow the inductive and loss resistance terms to be measured.

I used an ancient Wayne Kerr *B221A* transformer ratio arm bridge, recently recalibrated and capable of 0.1% accuracy at 1592Hz. This Bridge is especially useful for cable measurements since it directly reads the required loss factors of *R* for inductors, *G* for capacitors also the reactive and loss balances are completely independent one from the other.

Table 2. AC parameters of cables selected for frequency tests. Measured using Wayne Kerr B221A transformer ratio-arm bridge.

AC parameters	1592Hz					10kHz				
Cable under test	C	G	L	R	Z_0	C	G	L	R	Z_0
4.9m long	pF	μs	μH	mΩ	Ω	pF	μs	μH	mΩ	Ω
Coax styles										
75Ω Cat. 500	239.7	.001	1.98	192	297.2	240	0.01	1.98	198	146.2
75Ω CT100	269.6	.001	1.86	134	237.8	270	0.01	1.86	135	121.8
50Ω RG58C/U	469.5	.001	1.59	288	254.4	469	0.01	1.64	289	115.3
50Ω URM67	508	.001	1.52	52.7	115.6	507	0.01	1.5	54.8	68.4
3mm Mark 1	1,275	.055	0.88	58.3	72.4	1,240	0.07	0.90	59.2	38.5
3mm Mark 2	1,177	.015	0.88	55	73.4	1,180	0.02	0.91	56.9	39.2
Fig. 8 styles										
2192Y bell wire	391.4	.329	3.62	379	312.8	341	1.8	3.63	378	161.5
42 strand	260	.143	3.89	245	321.7	234	0.81	3.9	246	177.9
42 strand modified	58.8	.009	6.08	244	714.5	52.4	.001	6.22	250	441.1
79 strand	341.8	.206	3.37	84.2	180.4	304	1.1	3.36	85.8	121.2
2mm twin special	375	.017	2.55	99.1	181.8	368	0.03	2.56	103	106.8
Supra Ply 2.0	882	.481	1.81	91.3	108.4	823	3.56	1.84	91.3	61.2

to maintain test amplifier stability and avoid output transistor overheating. This made the intended plots of measured results impossible.

While the circuit Q, or test voltages used, changed with frequency, at each frequency, the test conditions were held constant, with change of cable or amplifier. This made it possible to tabulate cable rankings by amplifier, **Table 1**.

Cable measured parameters: To quantify the test cables parameters, each was carefully measured using four- terminal techniques, for dc resistance at 1A, also ac parameters at two differing frequencies. These parameters were applied to the transmission line equation to calculate the cables characteristic impedance by frequency, **Tables 2, 3**.

Cable in-circuit attenuation: Much emphasis has been made in tests[3,4,5,6] and speaker-cable brochures, regarding skin effect and its adverse affect on a cable's attenuation – even at frequencies as low as 2-3kHz. Attenuation was carefully measured by driving each cable with constant 4.00V rms via the mosfet amplifier and measuring the voltage across a 4.7Ω resistor to simulate a loudspeaker load. As expected, the change of attenuation for audio frequencies was negligible – hardly greater than experimental errors.

No tangible evidence of skin effect on measured attenuation at audio frequencies could be seen with the cable conductors tested, although attenuation changes relating to 'G' change were visible. For completeness, each cable was rated for low-frequency attenuation and deviation of this attenuation from 100Hz to 30kHz, **Table 4**.

Conclusion for resonant circuit tests: To my surprise on examining these tables, cable impedance was clearly important at frequencies much lower than 10kHz. Since several cables also changed ranking with change of amplifier and frequency, obviously some extra influence was involved, needing further experiment.

Additional tests

Following exploratory tests, I discarded 300Ω twin feeder and 75Ω television cables due to poor performance, substituting them with RG58C/U – a low cost 50Ω instrumentation cable. I then hand made two lower impedance coaxial cables and a low-impedance twin-line with much reduced capacitance relative to the *Supra Ply 2.0*. This gives pairs of coaxial cables of 75Ω, 50Ω and lower than 50Ω, in total 12 test cables, giving better characteristic spread. All additional cables are included in all the results presented here.

The 2mm twin-line special was built using 1.94mm² cross-sectional area conductors. Although similar in area to *Supra Ply 2.0*, this special has different insulation and wall thickness, resulting in only half the capacitance but a higher impedance.

Both coaxial cables, namely the 3mm mark I and 3mm mark II, have different wire cores, insulating materials and wall thickness. They were intended to have similar characteristic impedances and nominally 3mm² area inner conductors.

Table 3. DC resistance of cables selected for frequency tests. Resistances measured using four-terminal method by voltage drop at 1A constant current.

Cables under test	Resistance	Wire core	Cross section
4.9m long	**mΩ, dc**	**No and size**	**area, mm²**
Coax styles			
75Ω Cat. 500	185.5	1×1mm	0.78
75Ω CT100	129.3	1×1.12mm	1.0
50Ω RG58C/U	282	19×0.18mm	0.48
50Ω URM67	47.0	7×0.77mm	3.26
3mm Mark 1	51.7	37×0.32mm	2.97
3mm Mark 2	49.1	19×0.45mm	3.02
Fig. 8 styles			
2192Y bell wire	374	16×0.2mm	0.50
42 strand	243	42×0.2mm	1.32
42 strand modified	243	42×0.2mm	1.32
79 strand	78.8	79×0.2mm	2.48
2mm twin special	93.5	19×0.36mm	1.94
Supra Ply 2.0	85.8	120×0.15mm	2.12

Cable attenuation

With loudspeaker cables driving into typically 8Ω systems at currents required for a few watts, some signal loss due to cable resistance is inevitable. If consistent across the audio frequency band, this small loss is immaterial, but loss increasing significantly with frequency can be audible.

Two common methods exist for measuring these losses, where absolute loss matters then insertion loss should be measured.[11]

For speaker cables in practical systems, attenuation, giving change of loss by frequency, should measured. This method was used in these cable comparisons.

Loss test

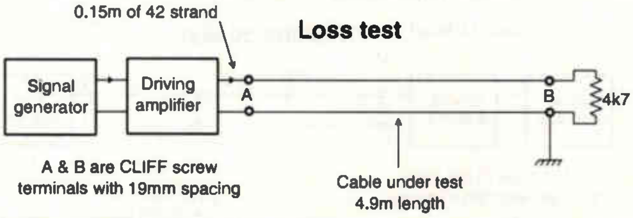


Table 4. Attenuation of 4.9m of cable by frequency. Results of applying a constant 4.00V to the cable, using the loss test set-up, and measuring voltage at 4.7Ω load. This level was chosen for optimum accuracy with the true rms meter used. Results are decibel load voltage deviation from 100Hz to 30kHz.

Cable under test	dB loss by frequency								
	100	300	1000	3000	10,000	20,000	30,000	100,000	Overall rating
Coax styles									
75Ω Cat. 500	0.355	0.355	0.355	0.355	0.355	0.355	0.422	0.867	7
75Ω CT100	0.2645	0.2645	0.2645	0.2645	0.2645	0.2646	0.3095	0.724	6
50Ω RG58C/U	0.5374	0.5374	0.5374	0.5374	0.5374	0.5374	0.5606	0.915	2
50Ω URM67	0.1093	0.1093	0.1093	0.1093	0.1093	0.1313	0.1313	0.4455	1
3mm Mark 1	0.0873	0.0873	0.0873	0.0873	0.0873	0.1313	0.1313	0.3095	3
3mm Mark2	0.0873	0.0873	0.0873	0.0873	0.0873	0.1093	0.1313	0.287	3
Fig. 8 styles									
2192Y bell wire	0.654	0.654	0.654	0.677	0.677	0.7242	0.795	1.777	11
42 strand	0.4485	0.4485	0.4485	0.4485	0.4485	0.5374	0.561	1.75	9
42 strand modified	0.4485	0.4485	0.4485	0.4485	0.4485	0.5606	0.724	2.914	12
79 strand	0.1533	0.1533	0.1533	0.1533	0.1533	0.2199	0.286	1.235	10
2mm twin special	0.1533	0.1533	0.1755	0.1755	0.1977	0.1977	0.2645	0.9878	8
Supra Ply 2.0	0.153	0.153	0.153	0.153	0.153	0.1533	0.1977	0.63	5

Amplifier cable drive circuits

Resonant circuit. The original 10kHz resonant circuit[1] comprised a 5.4mH inductor and 0.05μF capacitor. The inductor was in shunt to ground, replacing the speaker voice coil. The capacitor fed current from the driven amplifier via an 8.2Ω short-circuit protection resistor.

A second 3.9Ω resistor simulated the voice coil resistance, and was used to feed the inductor's voltage into the test cable and thus into the test amplifier.

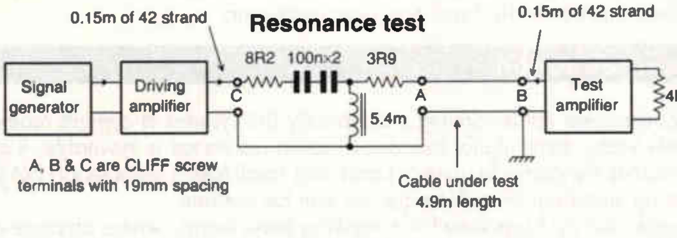
Due to the very high unloaded 10kHz voltage and current sustained by the capacitor, I used two 0.1μF 400V Siemens polypropylene B32650 types in series (Electrovalue part 50.1400).

The inductor was a 5.4mH 'Super Power Low Loss' 1mm wire having a Q of 15 at 10kHz, from Falcon Acoustics Ltd, Tabor House, Mulbarton, Norwich (Malcolm Jones). Both resistors were HSA25 wire-wounds.

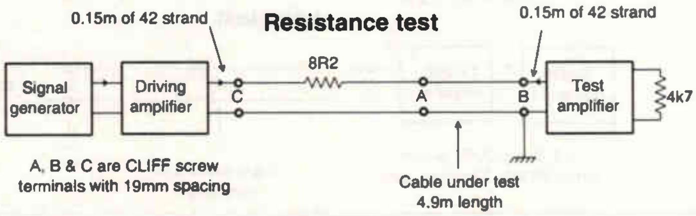
For the new additional frequencies, inductances and capacitances used were,

159Hz	30mH	33μF	not commercially available
1592Hz	5.4mH	1.85μF	as for 10kHz +1.8μF 400V Siemens MKC
10kHz	5.4mH	0.05μF	see above.
21.1kHz	1.15mH	0.05μF	inductor Falcon air core/LL 0.71mm wire.

The test amplifier input was grounded via a 4.7kΩ resistor. This is because my Self amplifier, built with better than 1% metal-film resistors and matched semiconductor pairs, suffered some instability when its input was grounded by lower values.



Resistive circuit. This comprised only an 8.2Ω *HSA25* resistor in series with the output of the driven amplifier. This resistor was found to have essentially constant impedance up to 20kHz.



The 50Ω URM67 coaxial cable has a 3.26mm^2 inner conductor giving less than 50mΩ loop resistance. As a result, these hand-made cables, together with the nine commercial cables, offered a balanced spread of impedance characteristics and dc resistance for the new tests.

To facilitate consistent measurements at varying frequencies, the resistive test circuit was amended, to simply use an 8.2Ω series resistor by removing the resonant circuits and the 3.9Ω resistor.

To eliminate earth-loop problems, all test voltages were measured using a custom built battery powered true rms meter with 1MΩ input impedance. This meter is based on an Analog Devices *AD637* precision rms-to-dc converter specified to 2MHz. To optimise measurement accuracy, the driven amplifier output was set to 4.00V for each measurement, chosen to ensure the lowest test voltages measured remained within the accuracy window for the *AD637* converter.

Resistive circuit results

Each result was entered into a dedicated *Visual Basic* 'cubic spline' curve fitting program, to plot the results. The cubic-spline' method[7] uniquely ensures the curve passes through each measured data point, thus highlighting any measurement errors, rather than producing a 'best-fit' curve form. These plots clearly show the interplay between dc resistance and ac impedance with change in frequency, **Figs 1, 2**.

A further anomaly can now be seen. The results by cable for both the mosfet and Douglas Self's bipolar amplifiers follow the resonant tests cable ratings at the lowest and highest frequencies. But the basic curve shapes in the all important 1kHz to 10kHz band – where the ear is most discriminating and sensitive – differ substantially.

To aid understanding, the cables' measured parameters were used to calculate their probable characteristic impedance changes with frequency, and plotted using the cubic-spline program. **Fig. 3**.

To ascertain the output impedances of both amplifiers used, the frequency tests were repeated with test points 'A' and 'B' short circuited and the 'B' voltages plotted. These voltages include the effect of the 0.15m of 42-strand cable and interconnection, measured as 7.8mΩ.

The 8.2Ω resistor used measured 8.08Ω. Simple calculation provided the correlation between measured voltage and amplifier closed loop output impedance, as indicated on the right y axis of the plot, **Fig. 4**.

To complete the results, the cable/amplifier test point B voltages were plotted, to reveal a final surprise. You might expect the cable giving maximum loudspeaker damping would result in the greatest point B test voltage. Not so, this also apparently depends on the amplifiers output impedance, the mosfet and bipolar amplifiers once more giving quite different curve shapes except at 1kHz where both show reasonably similar behaviour, **Figs 5, 6**.

With these test results, what conclusions can be derived ?

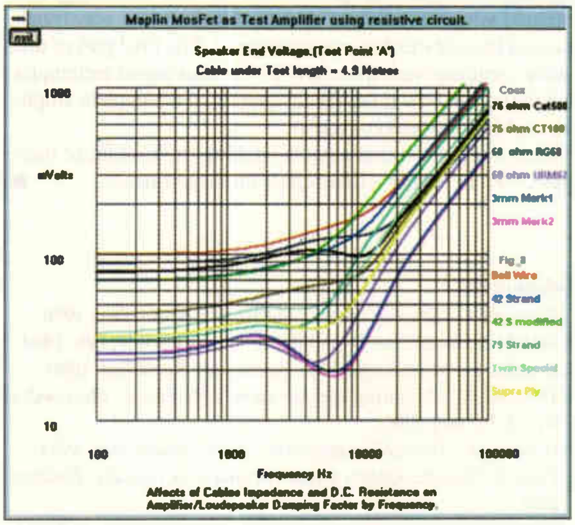


Fig. 1. Speaker 'end' damping voltage by test cable and frequency using Maplin mosfet amplifier, the resistive test.

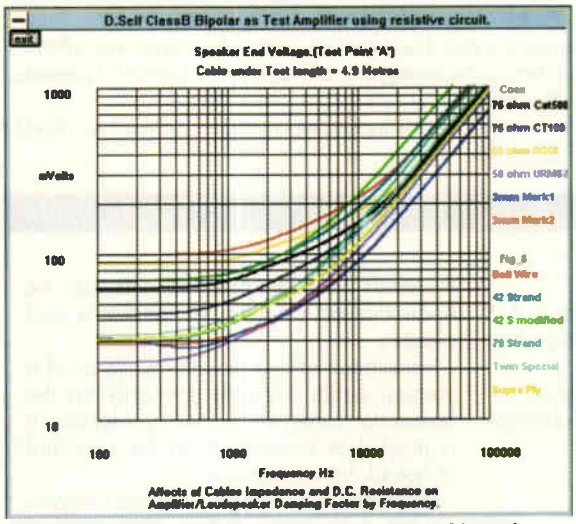


Fig. 2. Speaker 'end' damping voltage by test cable and frequency using bipolar amplifier in the resistive test set-up.

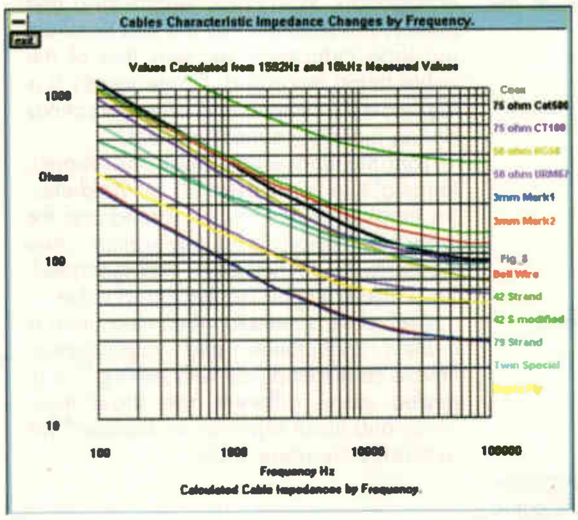


Fig. 3. Test cable characteristic impedance by frequency, based on the Wayne-Kerr bridge measurements.

Regardless of whether the amplifier is mosfet or bipolar, the idealised target is that any cable used does not itself degrade amplifier damping and has a minimal change on that amplifier's voltage measured with no connecting cables in circuit. All other conditions are maintained constant. Compare Figs 1, 2 with Fig. 4.

The lowest resistance cables tested, had a dc resistance of around 50mΩ. At 100Hz, assuming an 8Ω speaker system and the amplifiers used in these tests, damping factor was noticeably degraded. It remains to be seen if this degradation is audible.

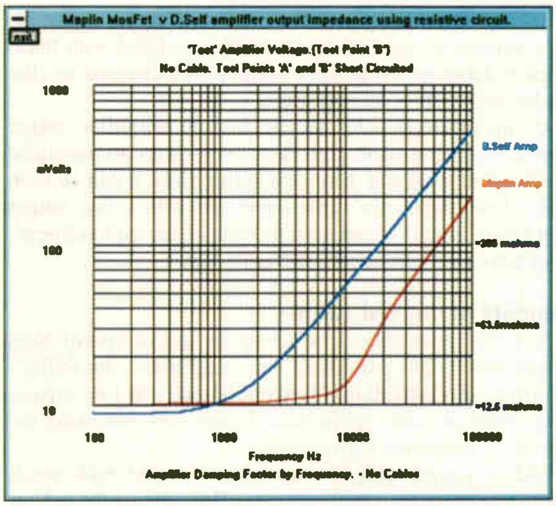


Fig. 4. Comparison of Maplin mosfet and Self's bipolar amplifiers output impedances by frequency using the resistive test set-up.

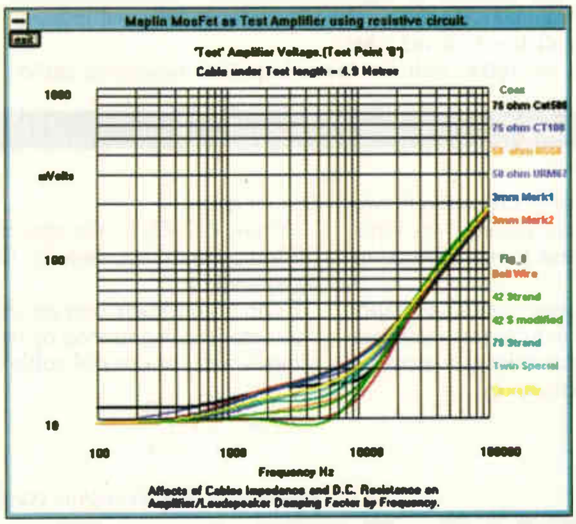


Fig. 5. Amplifier 'end' damping voltage by test cable and frequency using Maplin mosfet amplifier and the resistive test set-up.

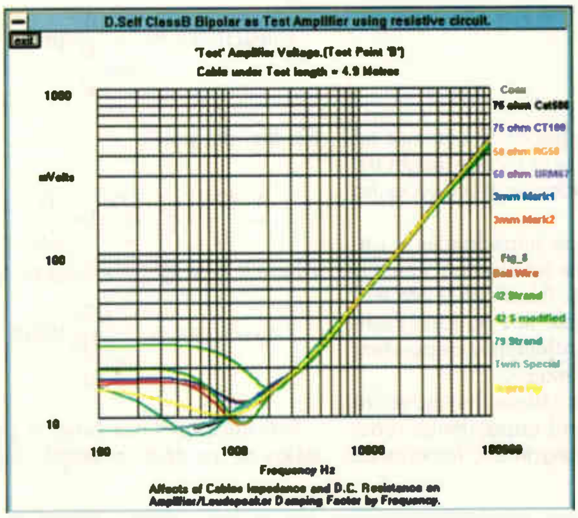


Fig. 6. Amplifier 'end' damping voltage by test cable and frequency using Self's bipolar amplifier and the resistive test set-up. Curves for 75Ω Cat 500, 50Ω RG58 and 50Ω URM67 are all underneath the Twin Special curve.

Scaling the measured results from the 4V test voltage used, to the 100dB sound-pressure level (0.9V into 8Ω) level used by Ben Duncan, suggests that speaker overhang could be 55dB down, i.e. similar to room background noise, at around 45dB sound-pressure level. Cable resistance much higher than 100mΩ could thus produce audible effects given a quiet room.

Clearly, both the resonant and resistive measurement methods confirm that to control speaker overhang near the bass resonance frequency exhibited by all loudspeaker cabinet designs, an extremely low resistance connection between amplifier and loudspeaker is essential.

Below 100Hz, every practical cable will have a characteristic impedance too high to be much assistance with loudspeaker damping. As a result, at the lowest frequencies, the cables resistance is all important.

At higher frequencies and increasing amplifier output impedance, a low cable impedance is required to maximise loudspeaker damping. From the result plots, it can be seen that a low impedance cable combined with a low output impedance amplifier can even provide increased loudspeaker damping with frequency increase, Fig. 1.

Benefits of coaxial cable

Low cable impedance, if achieved by use of unduly high capacitance, has resulted in amplifier instability.[6] Unfortunately, attaining a low impedance and low capacitance cable at audio frequencies is not easy, but using the coaxial construction helps.

With a coaxial cable, the outer braid can be made much lower resistance than the inner core. This reduces the cable's loop resistance for a given centre wire, preventing rf pickup from entering the amplifier's feedback loop and reducing radiation from the cable.

At 1kHz, with the lower impedance/resistance cables, impedance and dc resistance contribute almost equally to amplifier damping factor performance. Above 1kHz cable impedance dominates, especially when used with wide 'open loop' bandwidth bipolar or mosfet-output amplifiers.

So where are the promised speaker test results? Some preliminary tests had been performed but were summarily terminated when the tweeter of the workshop two way transmission line cabinet test system expired. The final part of this article continues with more low-cost measurement techniques and will show how these results pertain to a complete amplifier, cable and speaker system.

Once more, I ask that anyone wishing to shoot these findings down in flames - first repeat the experiments. ■

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Transmission lines

Transmission lines cables are made in two main formats each comprising two separated conductors. These formats are coaxial and line pairs.

In both cases, reduced conductor separation reduces series inductance, increases shunt capacitance and reduces the cables characteristic impedance, Z_0.

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

which at high frequencies can be approximated as,[8]

$$Z_0 = \sqrt{\frac{L}{C}}$$

This characteristic impedance assumes an infinitely long length or a shorter length terminated by this impedance. It produces no reflected wave.

All other termination impedances – i.e. mismatches – produce a reflection which is returned to the source. If both ends are mismatched and the cable has no loss, these reflections continue indefinitely dependent on the degree of mismatch.

At low frequencies, since the inductive reactance is small and capacitance reactance is large, the characteristic impedance can increase.

Where $R/L=G/C$, the special case of a 'distortionless' line, then Z_0 is frequency independent.

Certain constructs can be designed for characteristic impedance by their physical dimensions. For coaxial cable[8],

$$Z_0 = \frac{138}{\sqrt{\varepsilon}} \log \frac{D}{d}$$

where e is the dielectric constant of the insulator, and,

$$\text{Capacitance} = \frac{24.16\varepsilon}{\log \frac{D}{d}} \text{pF/m}$$

For the line pair[9],

$$Z_0 = \frac{276}{\sqrt{\varepsilon}} \log \sqrt{\frac{2D}{d}(1 + \frac{D}{2h})^2}$$

where h is height above ground, and,

$$\text{Capacitance} = \frac{12.07\varepsilon}{\log \frac{2D}{d}} \text{pF/m}$$

Transmission lines have a propagation delay dependent on length and dielectric materials used. In practice, this can be approximated to 6ns/m for commonly used plastics.

Inductance of two parallel wires or of a coaxial cable depends primarily on the separation between the two conductors. It is much less dependent on the size and shape of the conductors.

Inductance of a length of cable comprises two main parts – that of the inductance/unit length, and that of any terminating loop. With cable lengths of a few metres, it is possible that the end terminating loop inductance exceeds that of the cable being measured. Consequently it is important to minimise end wire separations during inductance measurement.

From the above equations, the capacitance of two wires depends on the dielectric constant of any insulators used and the wires dimensions and separation. Any measurement connections if well separated, have little effect on the measured value.

Much care is needed when measuring a cable's inductance and capacitance. Private correspondence with Jenving[10] suggested values different from those measured and those reported by Duncan[4] for ostensibly the same cable.

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022

The potentiometer and its potential

For a decade, the word potentiometer meant more than just a volume control. Harold Kirkham explores the potentiometer, and its use as a remarkably precise voltmeter having the capability to read to within a few parts per million.

When we say that there is a potential difference of so many volts between two points in a circuit, we are really saying that the potential is so many times bigger than the volt – a quantity that is known exactly. Forget, for the present, the fact that the volt itself has been changed many times, and as recently as 1990.

An analogue voltmeter obscures the situation somewhat, because an analogue voltmeter is essentially a calibrated spring. The comparison is made at the level of the force of a magnetic field and the force of a spring. A digital voltmeter, on the other hand, makes the comparative nature of the measurement obvious, since there is, buried in the internal circuitry, a reference voltage of some kind.

The digital voltmeter compares the reference voltage and the unknown, to produce a reading directly in volts. At the end of the last century, before there was any such thing as electronics, the potentiometer, along with a reference voltage and a galvanometer, did much the same thing.

This Leeds and Northrup version of the potentiometer is an adaptation of the Crompton arrangement, one of a series (K1 through K5) sold as recently as the 1980s. This one is a K2, dating about from the 1940s. It has three ranges, with full-scale readings of 1.6V, 0.16V and, believe it or not, 0.016V.

Reference voltage sources

A number of devices have served as reference voltages over the years. Since it was patented by Edward Weston – who had emigrated from Britain, and started a company in New Jersey – in 1892, the Weston cell has been the voltage reference of choice.

This cell **Fig. 1** consisted of mercury as the positive element and cadmium amalgam – a solution of one part of cadmium in seven parts of mercury – as the negative element. These materials could be obtained with a high degree of purity, which is an important factor in a cell whose voltage was to be as permanent as possible.

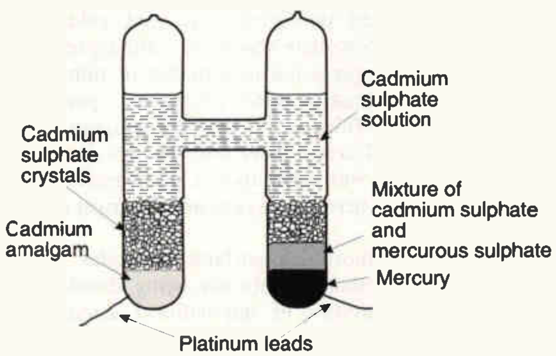


Fig. 1. The Weston cell has crystals of cadmium sulphate to ensure a saturated electrolyte. A cell like this, kept in a constant temperature oil bath, has a lifetime of many years.

The electrolyte was a saturated solution of cadmium sulphate, with cadmium sulphate crystals added to ensure saturation. A depolariser, mercurous sulphate, was added. The connections to an external circuit were made by platinum wires sealed into the glass container.

Voltage of the cell when constructed in accordance with the standard specification was 1.01859V at 20°C. The voltage at a temperature near 20°C could be estimated readily since the cell output decreased by 40ppm/°C.

Great care had to be taken to ensure that no appreciable current was taken from the standard cell, as the output was only constant on open circuit. Standard cells were thus only used in null methods of measurement, such as the potentiometer.

Potentiometer principles

In the potentiometer, **Fig.** 2, battery B sends a current through a slide-wire of uniform cross-section. Resistor *R* is a regulating resistance to control the current in the slide wire. It is desired to measure the voltage of the battery B_1, connected in series with a key and a galvanometer. A galvanometer was a device to indicate, rather than measure, current. It can be thought of as a sensitive centre-reading microammeter, except that many galvanometers would produce large deflections with less than a microamp. Typically,

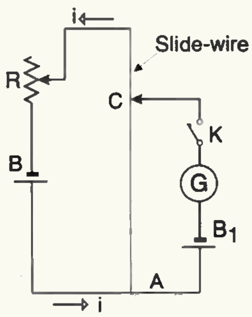


Fig. 2. The elementary potentiometer consists of a reference cell, galvanometer and key connected to the moving terminal of a slide-wire. A battery supplies the current.

only the zero or centre was marked on the scale.

Suppose that r is the resistance per unit length of the slide-wire, and that i is the current in it when the key K is open. Then, if the length AC is l, the voltage drop across AC is irl.

If key K is closed, current flows through the galvanometer in the direction of A to C, if the voltage drop across the length l of the slide wire is greater than the voltage of the battery B_1. Sliding contact C is adjusted until there is no deflection of the galvanometer. Length AC_1 is measured. This length can be called l_1, corresponding to battery B_1.

Battery B_1 is replaced by B_2, and contact C again adjusted until no current flows through G. With length AC_2 at l_2, writing the voltages of the batteries as E_1 and E_2, both of which must be less than the voltage of the supply battery B, gives,

$$E_1 = irl_1$$

$$E_2 = irl_2$$

so,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

A scale is provided on the potentiometer so that l_1 and l_2 may be read off. If one of the two batteries, say B_2, is a standard cell of known voltage, the voltage of battery B_1 is given by,

$$E_1 = \frac{l_1}{l_2} \times E_2$$

Note that when the potentiometer is balanced, no current passes through the battery under test, so the potentiometer effectively presents a very high resistance. Neither the standard cell nor the circuit being measured is loaded by the potentiometer.

The potentiometer works because it is possible to produce very uniform resistance wire. Of course, that uniformity would be spoiled if the user savaged the wire with a screwdriver as a sliding contact – as I remember doing to a slide-wire in an early physics class. Ordinarily, however, the various lengths could be measured with less than 1% uncertainty. Nonetheless, the approach so far described would be somewhat cumbersome.

Direct reading potentiometer

Col. Rookes Evelyn Crompton – founder of the company bearing his name – first modified the simple slide-wire form of potentiometer to provide improved resolution, and make the device direct reading, **Fig. 3**.

A graduated slide-wire AC was connected in series with 15 coils (resistors), each of which had a resistance exactly equal to that of the slide-wire, of the order of 10Ω. There were two moving contacts, sliding over the slide-wire and the studs of the resistance coils. Supply battery B was 2V, and R_1 and R_2 were variable resistances for the coarse and fine adjustment of the potentiometer current.

Galvanometer G was in series with key K, and a switch by means of which either the standard cell S or the battery whose voltage was to be measured could be connected.

In use, the potentiometer was first 'standardised,' i.e. made direct reading, by adjustment of the current from the supply battery as follows. A standard cell was connected to the ter-

Null versus deflection

In the 1880s, physicists were trying to 'determine' the ampere and the ohm, based on definitions originating in the centimetre-gramme-second system – itself not yet completely adopted for scientific use. These definitions led to apparatus that occupied a considerable amount of time and energy to set up and to use.

Most of those concerned came to believe that any method that did not require such effort must necessarily be inferior. The orthodox view was that the measurement of electrical quantities was supposed to involve skill and exertion, using complicated apparatus.

As an example, consider the tangent galvanometer, a device to indicate current. The current is passed through a circular coil, at the centre of which is freely suspended a very small magnetic needle – essentially a compass. Initially, the apparatus is set up with the plane of the coil aligned with the local Earth's field. Deflection of the needle is then given by,

$$I = \frac{Hr}{2\pi N} \tan\theta$$

where r is the radius of the galvanometer coil of N turns, H is the horizontal component of the Earth's magnetic field, and I the current.

Consider the difficulties. First, the Earth's field must be determined, and must not be disturbed by the fields of other current-carrying conductors. Second, the coil must be of known radius, and must be exactly vertical. The needle must be infinitely short, and at the centre of the coil.

The tangent galvanometer was far from direct reading, and needed considerable skill to use. There was a general feeling that, for precision work, only the zero point on an electrical instrument could be relied upon. All the well-known bridge methods – and the potentiometer – are nulling methods, requiring an accurate fix on only the zero of the instrument.

This view that the direct methods were inherently inferior was deeply held. Imagine the consternation when Professors William Ayrton and John Perry of the London City and Guilds College, Finsbury, introduced a series of direct reading electrical instruments, beginning in 1880. These first instruments were not very accurate – perhaps ±5% – but they were linear. They required only a constant multiplier, not a conversion table, to translate the reading in degrees deflection to the current or voltage. They were also easy to use, and could be connected more or less at will into circuits of any kind.

In 1881 Ayrton and Perry introduced the terms ammeter and voltmeter. While Ayrton and Perry instruments rapidly dominated the growing world of commercial electricity, they were looked down on by physicists as being both direct reading and pre-calibrated by an instrument maker, a middle-man upon whose skill physics was reluctant to rely.

It seems to have been overlooked that both the ruler and the stopwatch were direct-reading, pre-calibrated instruments. Potentiometric measurements were, being null measurements, quite acceptable.

By 1884, Ayrton and Perry had labelled the scales of their instruments directly in volts and amps. In 1894, Ayrton and another colleague, H. C. Haycraft, presented a paper called 'A Student's Simple Apparatus for Determining the Mechanical Equivalent of Heat' at the Physical Society in London. This paper showed that by using an industrial strength current of about 30A, measured by a direct-reading ammeter with $^1/_3$% accuracy, and a voltage of about 9V, measured by a direct-reading voltmeter with an accuracy of $^1/_5$%, the mechanical equivalent of heat (Joules' constant) could be determined in about ten minutes.

The world of physics was, to put it mildly, quite agitated. E. H. Griffiths, a Cambridge Fellow, had spent the five years before 1893 making 100 separate evaluations to find a value of 778.99 foot-pounds per thermal unit. A year later he had discovered an error in his work, and published a revised value of 779.77. Now here was Perry claiming results of equal precision in a matter of minutes. The indignation of the physicists – particularly Griffiths, as can be imagined, but also George Carey Foster and Charles Vernon Boys – was such that a permanent split occurred between physics and electrical engineering.

This almost religious faith in complex, non-direct methods is only now being abandoned in the physics of international standards. Electrical engineering meanwhile, has, gone on to provide instrumentation of greater and greater accuracy and wider and wider applicability.

minals marked *SC* and the potentiometer was set to read, directly, the known voltage of the standard cell, corrected to the room temperature if necessary. If a Weston cell was used, contact P_2 would be placed on the stud labelled 1.0 and contact P_1 on 0.01859 on the slide wire.

Resistances R_1 and R_2 were then adjusted until there was no deflection of the galvanometer when the key *K* was pressed. Leaving resistances R_1 and R_2 at these settings, the switch was changed so as to connect the battery whose voltage was to be measured. P_1 and P_2 were then adjusted until the potentiometer was again balanced. The reading of the potentiometer scale would then give the value of the unknown voltage directly.

Once the potentiometer had been standardised, the reading was not only direct, it was semi-digital. Contact P_2 provided a value for the first two digits of the measurement, and the sliding contact added two or three more, depending on how carefully the balancing was done. Standardising was tedious however. Accurate measurements required that the standardisation be performed before and after the measurement – a lot of adjusting.

To simplify operation, a 'standardising device' was used. Remember that the standardisation process really amounted to a fine tuning of the current through the potentiometer. Current was adjusted so that the voltage drop across the section of the potentiometer's resistance corresponding to the reading of the standard cell was equal to the cell's voltage. Thereafter, current in the potentiometer was left alone.

A standardising device was simply a series resistor of the same value, adjusted at the factory, so that when this value of current passed through it, the volt-drop would be equal to the voltage of the standard cell. It made no difference where the potentiometer switches or slide-wire were set, since these did not affect the series resistance.

Switches reconfigured the potentiometer circuit to allow the galvanometer to indicate balance in the normal way during standardisation. Usually, the standardising resistor could be trimmed by the user to correct for temperature changes, which affected the Weston cell voltage.

A standardising device of this kind meant that the process of setting up the potentiometer was much simpler and faster, and there was less wear and tear on the moving parts. The setting of the potentiometer made no difference during standardisation. Thus, if many measurements were to be made of similar voltages, they could be performed with little more than small adjustments to the slide wire, and the standardisation could be checked periodically. This was often the case: the two main industrial applications of the potentiometer were the calibration of other direct-reading voltmeters and ammeters, and the calibration of thermocouples.

Range changing

The potentiometer could easily be made to read lower values of voltage by decreasing the current in the series coils and the slide-wire. An arrangement like that shown in **Fig. 4** could reduce the current by a factor of 10 and a factor of 100 while keeping the load seen by the battery constant. In this way, the standardising process would be valid for all the scales.

Voltages higher than a few volts required the use of a device called a volt-box. This was no more than an external voltage divider, arranged to present a suitable voltage, less than 1.6 volts or so, to the potentiometer.

Evolution of the potentiometer

Over the decades, the potentiometer evolved from a simple device consisting of a slide-wire and a galvanometer to become an elegant and accurate system for measuring steady voltages of more or less any magnitude. Several companies included a potentiometer in their product line, and each was different in some way from the others. Some used a parallel

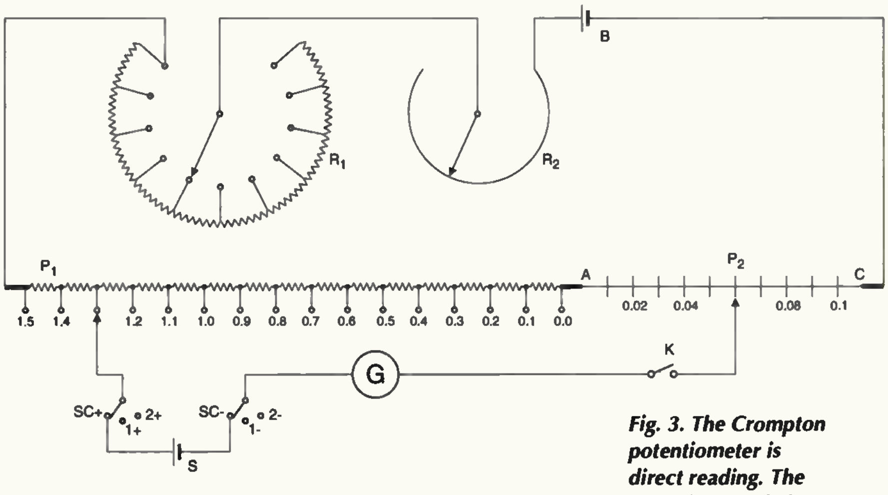


Fig. 3. The Crompton potentiometer is direct reading. The range is extended and the resolution is improved by the series resistors.

standardising device.

Some potentiometers used multiple slide wires, to provide increased resolution. Some included a circuit in parallel with the slide wire that allowed the slide some latitude around zero so that a true zero could be read. The potentiometer from Leeds and Northrup, described below, had only one slide-wire, but it was capable of some very impressive results.

Leeds and Northrup's potentiometer

The body of Leeds and Northrup's potentiometer, shown on the first page, measures by 400mm wide by 230mm deep. The big drum on the right of the potentiometer, called the hood, contains the slide-wire. It is 150mm in diameter, and houses 11 turns of wire of 0.63mm diameter, for a total of over 5m of wire.

Probably, the wire is manganin, so as to reduce the thermoelectric voltages in the system. Controls on the right are the coarse, medium and fine current adjustments. The large knob near the middle is the coarse voltage adjustment, in steps of 0.1V. The three buttons in front of it are low, medium and high sensitivity keys for the galvanometer. The knob at the back, left, is the fine control for standardising: it is set to the voltage from the standard cell, adjusted for temperature. The middle switch on the left is the range selector. The front switch on the left sets the function to measure or standardise. The back has connections for the unknown voltage, the galvanometer and both the reference and the supply battery.

According to the manufacturer, the hood could be set and read to an accuracy of one thousandth of a turn. Its scale has a two hundred tick marks 5mm apart, so this claim is not exaggerated. Thus, in its least sensitive setting, the potentiometer would read to 1.6 volts: each of the 15 switch positions corresponded to 0.1V, and each turn of the hood was 0.01V. Apparently, resolution was 0.01/1000 V, or about 6ppm.

Could the potentiometer really be this good? Consideration

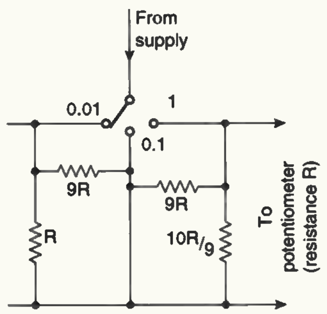


Fig. 4. A resistor network like this is used to produce a lower value of full scale voltage without changing the standardisation.

of the circuit shows that uncertainties in the values of all the coils (resistors) in series with the slide-wire would add directly in rms fashion to the uncertainty of the measurement. There are 15 such coils. In fact, while bridge circuits exist that would enable the manufacturer to produce resistors that were within a few ppm, it is unlikely that the overall uncertainty could be much lower than 10 or 20 ppm. It may be that the uncertainties in the resistance values of the coils are not uncorrelated, leading to somewhat worse performance.

To achieve maximum precision, it was necessary to take precautions to cancel thermal emfs. To do this, the potentiometer was operated with the battery disconnected. A wire shorted the terminals normally used for the unknown voltage, and the galvanometer was adjusted to read zero when the key was pressed.

This procedure had the effect of forcing the contribution of the thermal emfs to zero. If the hood had been rotated prior to this adjustment, a 'cooling-off' period was recommended for the slide-wire and its contact.

In use, the potentiometer power came from a 2V battery, or two dry cells. The dry cells were not recommended because their output would fall with use, and frequent standardising would be needed. The standard cell and galvanometer were not included as part of the potentiometer.

Present performance

Although I bought my potentiometer as a conversation piece, rather than a precision instrument, I was curious about its capabilities. The first difficulty in checking it was finding a standard cell. While I did eventually find one, the first tests I performed used a laboratory power supply instead.

I set the power supply to a value of 1.0186 as indicated on a $4^1/_2$ digit dvm, and used another laboratory supply, set to 2.0V, to power the potentiometer. For a galvanometer, I used a centre-reading microammeter. After standardising the potentiometer, I checked the value of the open circuit voltage of various dry cells and rechargable cells, with the dvm and the potentiometer at the same time.

The readings sometimes differed by one in the last digit, indicating that the error was less than one part in 15,000. It may also be that this error was due to nonlinearity in the dvm. It seemed that better performance would have been possible had I been able to find a more sensitive galvanometer.

Later tests with the standard cell gave much the same results. The standard cell, from another antique, was of unknown history. Nevertheless, its open circuit voltage was exactly 1.0186 V, as expected.

Evidently, its age notwithstanding, this potentiometer was readily capable of better than 100 ppm uncertainty. A better dvm would be required to check the device's performance more closely.

Concluding remarks

It is easy to see why the potentiometer was so favoured by early metrologists. It is relatively easy to use, remarkably stable, and capable of excellent accuracy. Potentiometric methods were used for calibrating transfer standards until quite recently in the national standards laboratories such as the National Physical Laboratory, NIST and the National Research Council of ■

The author would like to thank Tom Gedman of Honeywell-Leeds and Northrup for taking the time to track down for me a copy of the owner's manual for the potentiometer.

Standards

Until the French adopted the metric system, their standards for units of measurement had been somewhat vague. The development of this now internationally used system was highly political, and its adoption, beginning in about 1790, was slow and widely resented.

Among other things, the adoption of a standard measure reduced the opportunity for the middle-man to profit from the small differences between measures of the same name in different regions of France.

By the mid-1880s, when there arose the need to standardise the units for measuring the electrical quantities, the metric system was quite widespread. At the time, what we now call electrical engineering was part of physics.

The physicists thought it made sense to define the amp and the ohm in terms of 'natural' quantities, such as the metre and the kilogramme. It seems to have been overlooked that the metre was arbitrarily based on a division of a meridian running through France, and that the estimate of the meridian was rather approximate. The kilogram was 'natural' only because it was based on the weight of a cubic centimetre of water.

The unit of current was defined as 'that current which when passed through a wire of negligible diameter in the arc of a circle of length 1cm and radius 1cm will produce a force of one dyne on a unit magnetic pole placed at the centre.' The ohm was defined as 'that amount of resistance which when subject to a unit current for one second would dissipate one erg.' The volt was a derived unit, based on these two definitions.

Apart from the difficulty of finding a unit magnetic pole, the definition of unit current was far from practical. Wire could scarcely be of negligible diameter compared to 1cm, and the effect of stray fields caused by the wires going to and from such an apparatus as defined could hardly be neglected.

A practical means of determining the ampere derived from the definition was the current balance, originally associated with the name of Lord Rayleigh, in which the force created by the current was 'weighed.' Current balances have been made at the National Physical Laboratory (NPL) in the UK, and at the National Institute of Standards and Technology (formerly the Bureau of Standards) in the US.

Over the years since these quantities were first defined, there have been many revisions. The ampere is still defined by a force; it is now that steady current which will produce between two infinitely long parallel conductors 1 m apart in a vacuum a force of 2×10^{-7}N/m.

But the volt is fixed in terms of the voltage across a Josephson junction maintained at the temperature of liquid helium and irradiated with microwave energy of known frequency, and the ohm is fixed by the quantum Hall effect. These represent departures from the earlier practice in two important ways.

First, the units are fixed by what are called 'representations,' something that produces the same kind of effect. The volt is fixed in terms of something that produces a voltage, and the ohm by something with a well-defined resistance, rather than in terms of length, mass and time.

Secondly, the representations automatically provide 'recipes' for practical standards. Such standards used to be called secondary standards – the Weston cell used in potentiometric work is an example – and were capable of fixing the quantity with less precision than was desired for a standard unit. This defect no longer applies: the volt is fixed to a few parts in 10^7, i.e. less than 1 part per million, and the ohm to a few parts in 10^8 by the present representations.

The new volt and ohm can be seen as part of a trend toward basing standards on quantum effects and doing so with a recipe that leads to a reproducible result. Thus, the second and the metre are both now based on material spectra.

Work under way to redefine the kilogram – the only standard that is still based on an artifact, in this case a lump of metal. One approach is based on an accurate determination of Avogadro's number, perhaps from the X-ray spectrum of ultra-pure crystalline silicon, something made possible by modern semiconductor technology.

In an ironic twist, another way would be to use the current balance in reverse: rather than have the kilogram fix the ampere, the ampere, which can be derived from the quantum representations of the volt and the ohm, would fix the value of the kilogram.

High-speed analogue capture

Pei An's analogue-to-digital system captures data at megahertz rates, but having its own data buffer, it can be conveniently interfaced via the pc's com or printer port.

My last article in *Electronics World* described a computer-based precision data logging system[1]. Although this system was capable of measuring very small signals, its conversion rate of a few hertz was low.

There are many situations where high speed data acquisition is required. For example, to digitise a video signal, a conversion rate of several megahertz is required. In applications using ultrasonic waves, frequency of the wave is in the range from several kilohertz to several megahertz. High-speed conversion is also needed to analyse fast transients.

This article describes a computer-based high speed data acquisition system. The maximum sampling rate is 8MHz and this can be programmed in eight steps, giving 4MHz, 2MHz, 1MHz, 500kHz, 250kHz, 125kHz and 63kHz.

The a-to-d converter has six-bit conversion accuracy. This may be inadequate in some applications, but, the system can be upgraded using higher resolution a-to-d converters.

A further feature of this system is that it not only reads data into the computer but also outputs data. Output data can be used for triggering or synchronising external circuits connected to the system. For convenience, the system can be connected to a pc's printer or COM port via simple hardware, **Fig. 1**.

The data logger is built around readily available components and can be constructed on a single-sided pcb.

Table 1. A selection of flash a-to-d converters.

Designation	Technology	Speed	Resolution	Supply voltage	Manufacturer
CA3304E	CMOS	25MSPS	4bit	3-7.5	Harris
CA3306CE	CMOS	15MSPS	6bit	4.5-5.5	Harris
HI3-5701K-5	CMOS	30MSPS	6bit	4.5-5.5	Harris
HI3-5700J-5	CMOS	20MSPS	8bit	4.5-5.5	Harris
MC10319P	Bipolar	25MSPS	8bit	4.5-5.5	MOT
MP7684KN	CMOS	20MSPS	8bit	5	MP

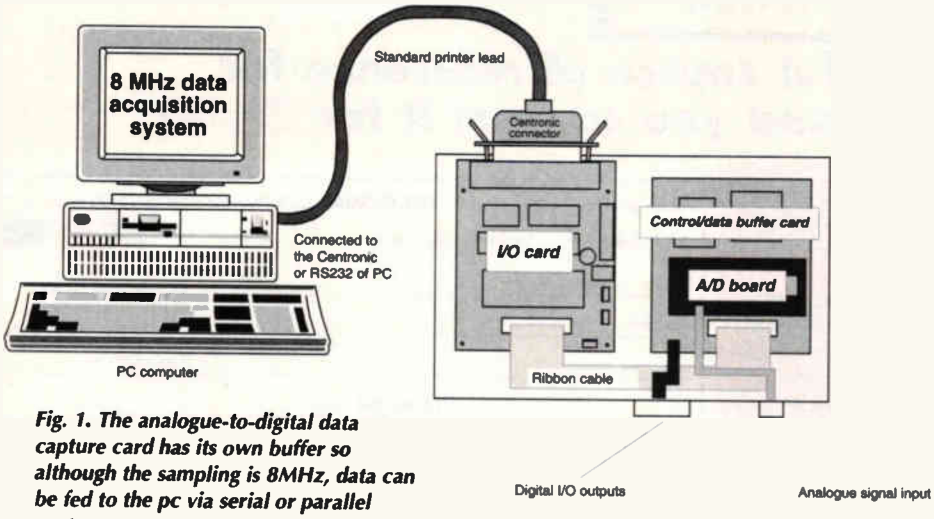


Fig. 1. The analogue-to-digital data capture card has its own buffer so although the sampling is 8MHz, data can be fed to the pc via serial or parallel ports.

Flash a-to-d converters

Conversion rates as high as several megahertz can be achieved using flash conversion technology. The principle of flash converters is that the input signal is compared with all possible subdivisions of the reference voltage at the same time, **Fig. 2**.

The reference voltage is divided by a series of resistors. The step is one least-significant bit interval in the middle and a half least-significant bit interval at the two ends. Reference input to the bottom comparator is a half least-significant bit and the second one from the bottom is $1^1/_2$ least-significant bits.

An input signal of zero results in no comparator switching. An input of between $^1/_2$ and $1^1/_2$ least-significant bits causes the lowest comparator to switch. An input signal of between $1^1/_2$ and $2^1/_2$ least-significant bits causes the lowest two comparators to switch, and so on.

Output generated by the comparators is converted to binary via an encoder circuit.

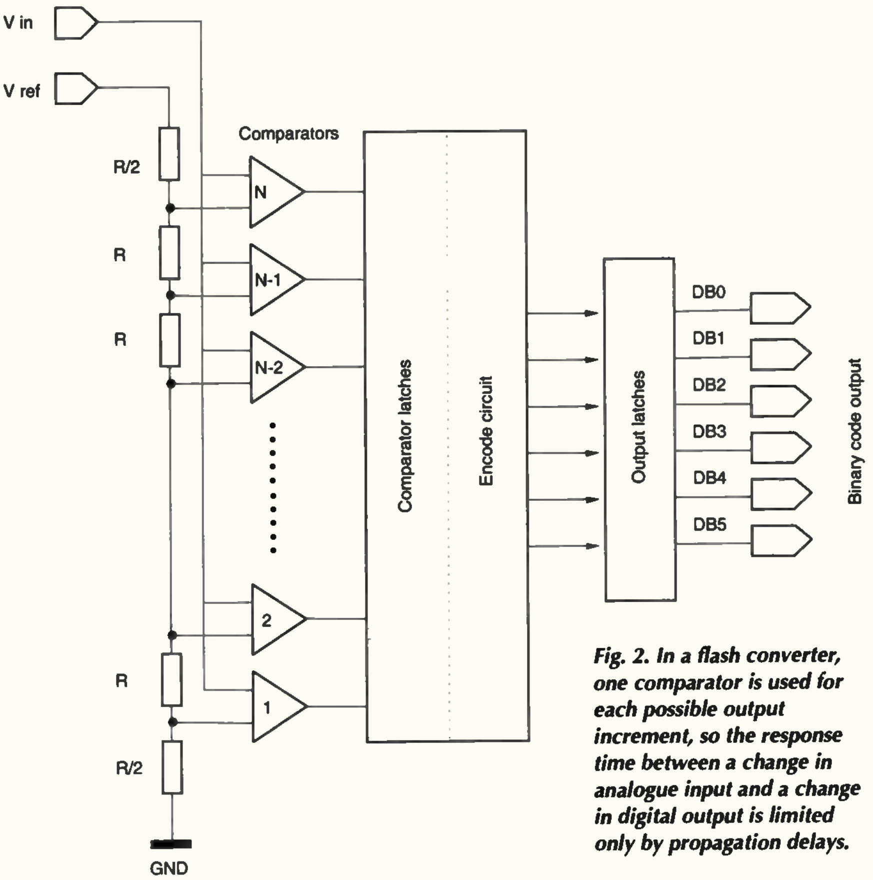


Fig. 2. In a flash converter, one comparator is used for each possible output increment, so the response time between a change in analogue input and a change in digital output is limited only by propagation delays.

Obviously, the number of comparators grows rapidly with increase of accuracy. An *n*-bit converter requires 2^n comparators.

A few of the flash a-to-d converters currently available are listed in **Table 1**. The circuit described here incorporates a *CA3306CE* flash converter. This IC has a conversion rate up to 15MHz and 6-bit conversion accuracy. It has 64 comparators and requires a power supply from 3 to 7.5V. Power consumption is about 50mW.

Facilities for two or more converter ICs to be connected together are included in the *CA3306* architecture. Connecting two converters in series doubles the conversion while parallel connection of two devices halves the conversion time.

Figure 3 shows the *CA3306* pin-out. Inputs V_{DD} and V_{SS} connect to the positive and negative, or ground, rail of the power supply. Data outputs are labelled B_1 to B_6 while overflow is indicated on pin 2.

There are two enable pins, CE_2 and $/CE_1$. When CE_2 is high and $/CE_1$ low, converted data appears on the data outputs. Otherwise, the outputs are in high impedance state. Pin 7 is a clock input while the phase pin controls the sequential operation of a-to-d conversion. When the phase pin is high, the rising edge of the clock starts a sampling cycle.

When the clock is high, comparators compare the input signal with the reference. At the falling edge of the clock, converted data from the comparators is latched into the comparator latches. During the low state of the clock, the data propagates through the encode circuit and the encoded data appears at the input of the output latches.

At the next rising edge of the clock, the data is latched into the output latches and appears on the pin. Simultaneously, it initialises a new sampling cycle. As a result, the output of the converted data is not for the same conversion cycle, it is for the previous one. Pins V_{ref-} and V_{ref+} supply the voltage reference for the a-to-d converter. Normally, the negative reference input connects to the digital ground. Positive reference V_{ref+} connects to a voltage anywhere between 1V and power supply voltage.

Acquiring data

In this design, a data buffer approach achieves sampling rates as high as 8MHz. Once a reset signal is issued from a computer, the internal control logic takes the control. It triggers the flash a-to-d converter to start a conversion and then latches the previous result into the data buffer.

This data reading cycle is repeated at a rate determined by the clock and runs until the data buffer is full. Next, the computer reads the data from the data buffer via the printer or RS232 ports.

The data acquisition system comprises six functional blocks:

- programmable clock generator
- internal control unit
- data buffer
- a-to-d converter unit
- signal conditioning unit
- interfacing unit.

Figure 4 shows the system's block diagram while **Fig. 5** is the circuit. The clock generator synchronises all the operations.

Accuracy of the analogue-to-digital conversion is determined by the a-to-d converter used. Capacity of the data buffer 32Kbyte. The logic control unit manages the timing sequence of triggering the a-to-d converter and storing the data into the buffer. It is also used when the computer reads data from the buffer. Data transactions between the computer and the data acquisition board are controlled by the interfacing unit.

Non-inverted and inverted clock signals, CLK, and /CLK are supplied by the programmable clock generator, which incorporates an *EXO-3*. This device includes a 16MHz crystal and is equipped with an eight-stage programmable frequency divider.

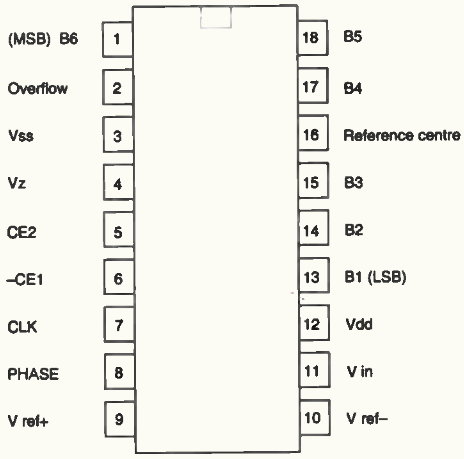


Fig. 3. Harris's CA3306 c-mos flash converter operates up to 15MHz. It only resolves to six bits, but it has facilities for using multiple devices to increase speed or resolution.

Division by 2 to 2^8 in eight-steps of the original frequency is selected by pins A, B and C. Clock signal is output at pin D.

In operation, the ST pin is tied to logic 1. **Table 2** shows programming of the clock, where F_0 is the original frequency of 16MHz.

Three output lines of port B of the *8255* programmable peripheral interface control lines A, B and C, Fig. 4. Power supply should be between 3V to 6V and supply current is about 10 mA.

The system allows other types of flash a-to-d converters to be used. Two control lines feed

Table 2. Programmable divider addresses.

C	B	A	ST	Divide output D
0	0	0	1	$F_0/2$
0	0	1	1	$F_0/4$
0	1	0	1	$F_0/8$
0	1	1	1	$F_0/16$
1	0	0	1	$F_0/32$
1	0	1	1	$F_0/64$
1	1	0	1	$F_0/128$
1	1	1	1	$F_0/256$

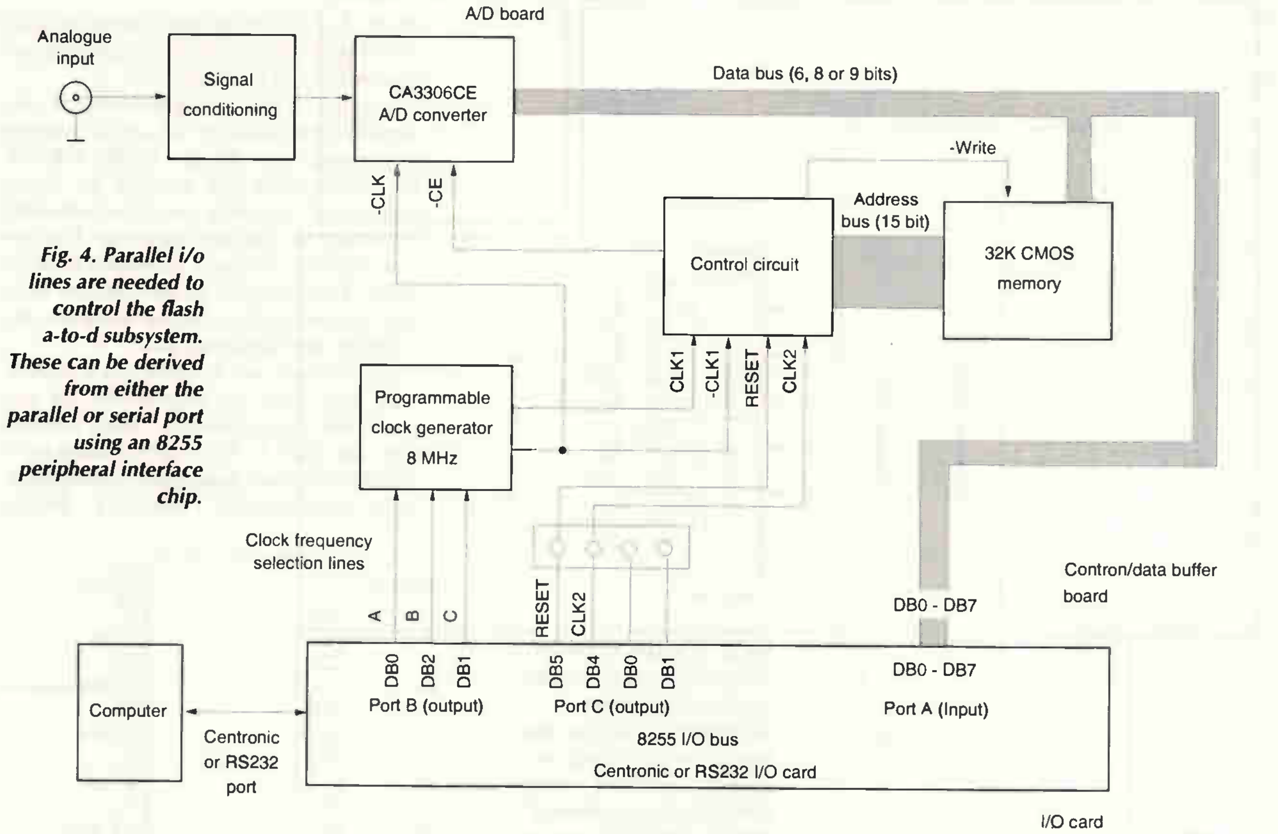


Fig. 4. Parallel i/o lines are needed to control the flash a-to-d subsystem. These can be derived from either the parallel or serial port using an 8255 peripheral interface chip.

Applying the card

Turbo Pascal 6 software has been developed for controlling the data acquisition system. The photographs show the software in operation. The small window in the centre shows the waveform digitised into the computer. In this example, the wave on the screen is a signal used to drive an ultrasonic transducer and has a frequency of about 40kHz. Obviously, this wave is not a sine wave. Sampling rate is shown at the bottom of the screen. In this example, it is 1500kHz. The program provides several functions:

Key	Operation
Any	freeze the waveform
E	expand the waveform
S	save the waveform,
F	calculate waveform frequency, for period wave only
C	change clock rate: 8, 4, 2, 1, 0.5, 0.25MHz
T	perform fast Fourier transformation (FFT)
H	view help file
Q	quit program

The bottom photograph shows the spectrum of the above signal derived by pressing 'T'. Horizontal axis is frequency and the vertical axis is the amplitude. There is a cursor on the window which is moved right or left using arrow keys. Frequency at the cursor position is shown below the window.

The example shows that the first peak on the spectrum is 40.203kHz. As the input signal is not a sine wave, other frequency components exist. The software provides several functions:

Up arrow	amplify amplitude of spectrum curve
Down arrow	attenuate amplitude of spectrum curve
Left arrow	move cursor left
Right arrow	move cursor right
Return	back to main menu

Software available from the author – used in conjunction with the parallel or serial interface card and flash a-to-d converter – allows capture of waveforms, like the one shown in the top photograph. It also allows waveform analysis. The spectrum of the above waveform is displayed in the bottom photograph.

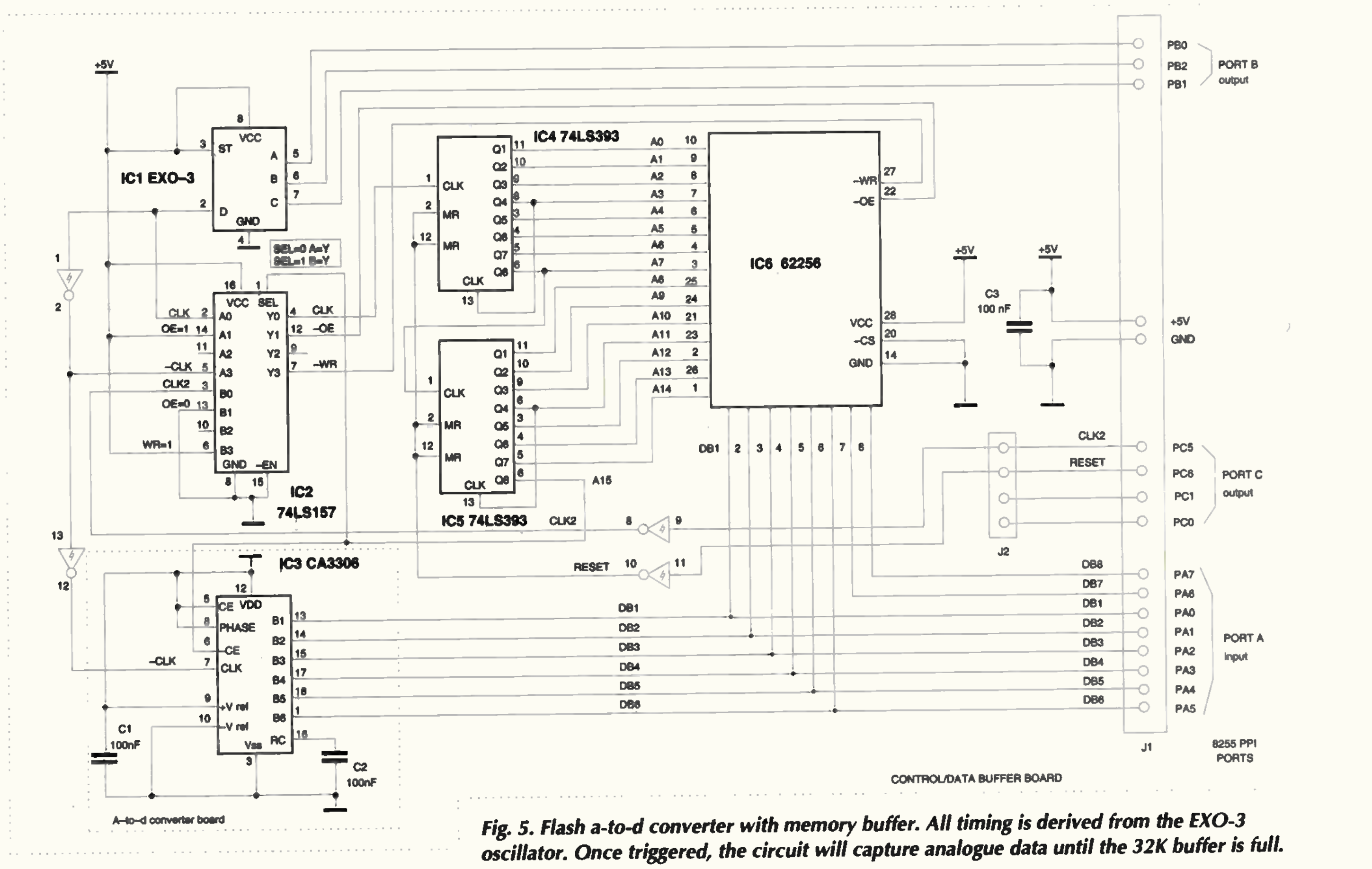


Fig. 5. Flash a-to-d converter with memory buffer. All timing is derived from the EXO-3 oscillator. Once triggered, the circuit will capture analogue data until the 32K buffer is full.

the a-to-d converter unit, namely CLK and /CE. Eight data lines, of which only six are used, connect to the data bus of the data buffer.

A low-to-high transition on the /CLK line starts a-to-d conversion. With /CE held low, the converted data appears on the data bus, otherwise, the data bus is in high impedance state. Data buffer IC_6 is a *43256* 32K static ram. Its data bus connects to the a-to-d converter unit.

All 15 address bits, together with write control and output enable signals, connect to the internal control unit. This unit manages the internal timing sequence. It is based on a *74LS157* data selector, IC_2, and two cascaded *74LS393*s, $IC_{4,5}$.

There are four separate data selectors within the *74LS157*. When the SEL input is low, inputs A_{0-3} connect to outputs Y_{0-3}, respectively. When SEL is high, B inputs are connected to the outputs, **Fig. 5**.

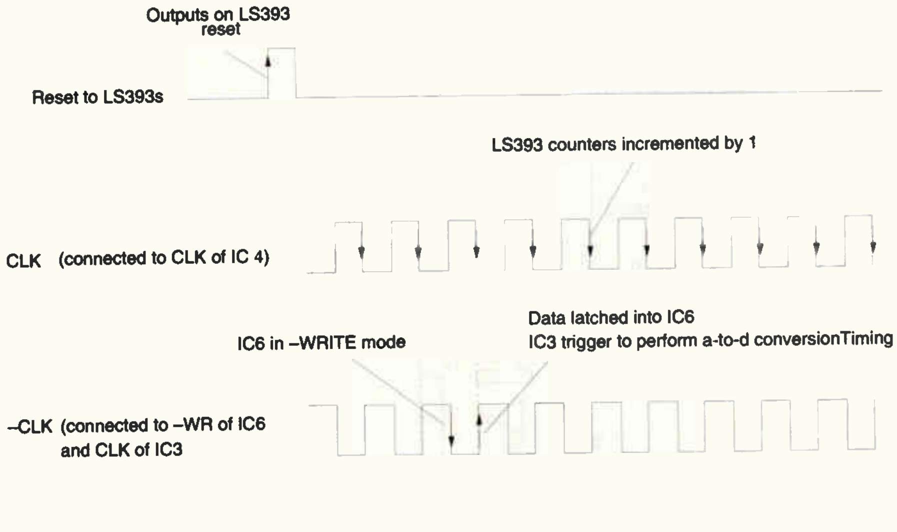
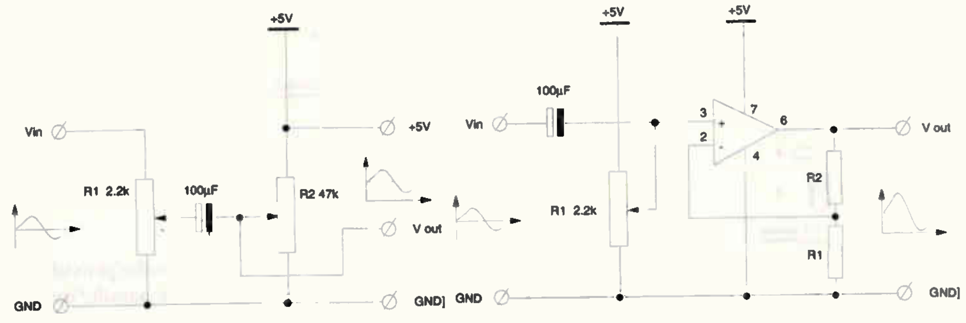
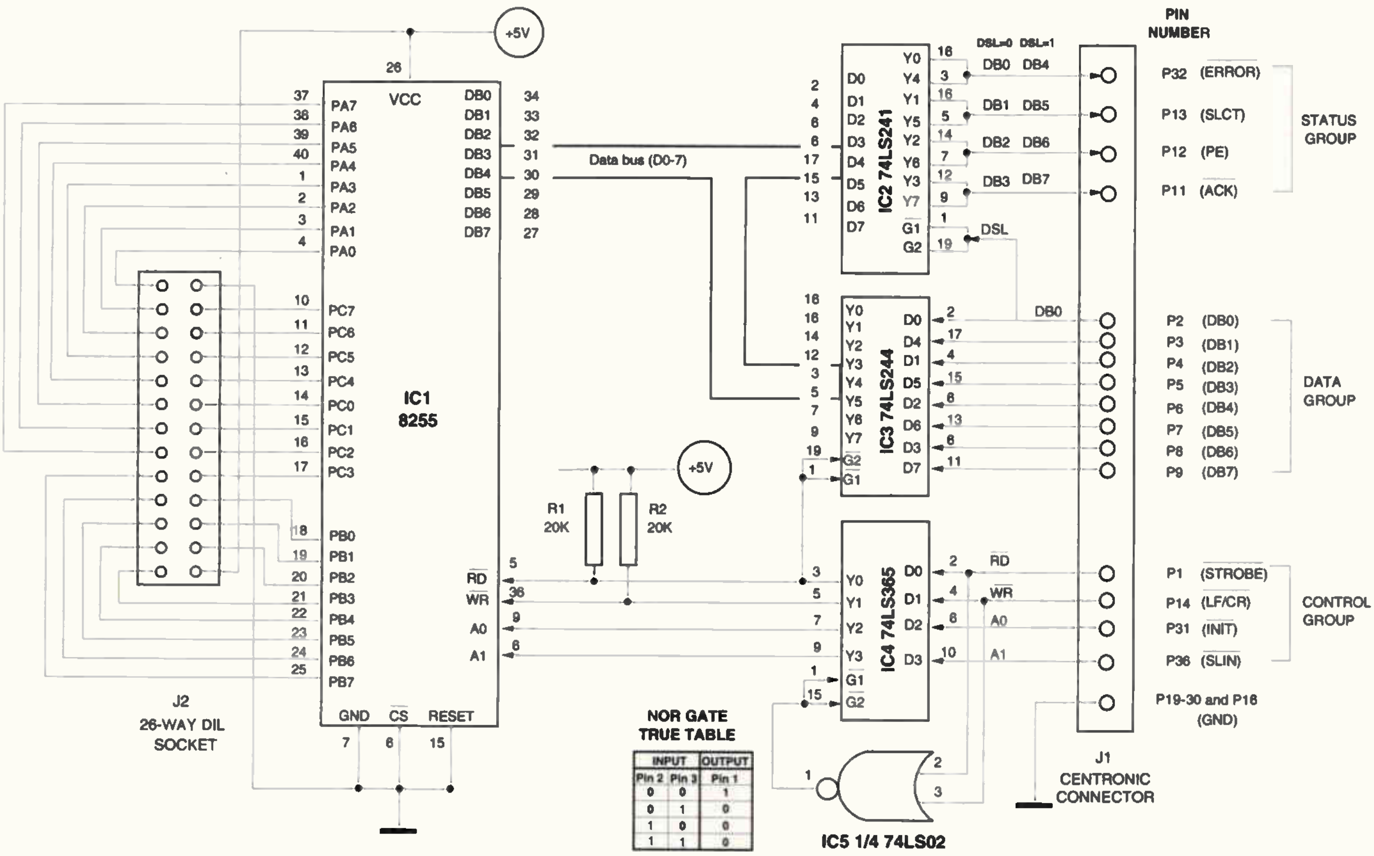


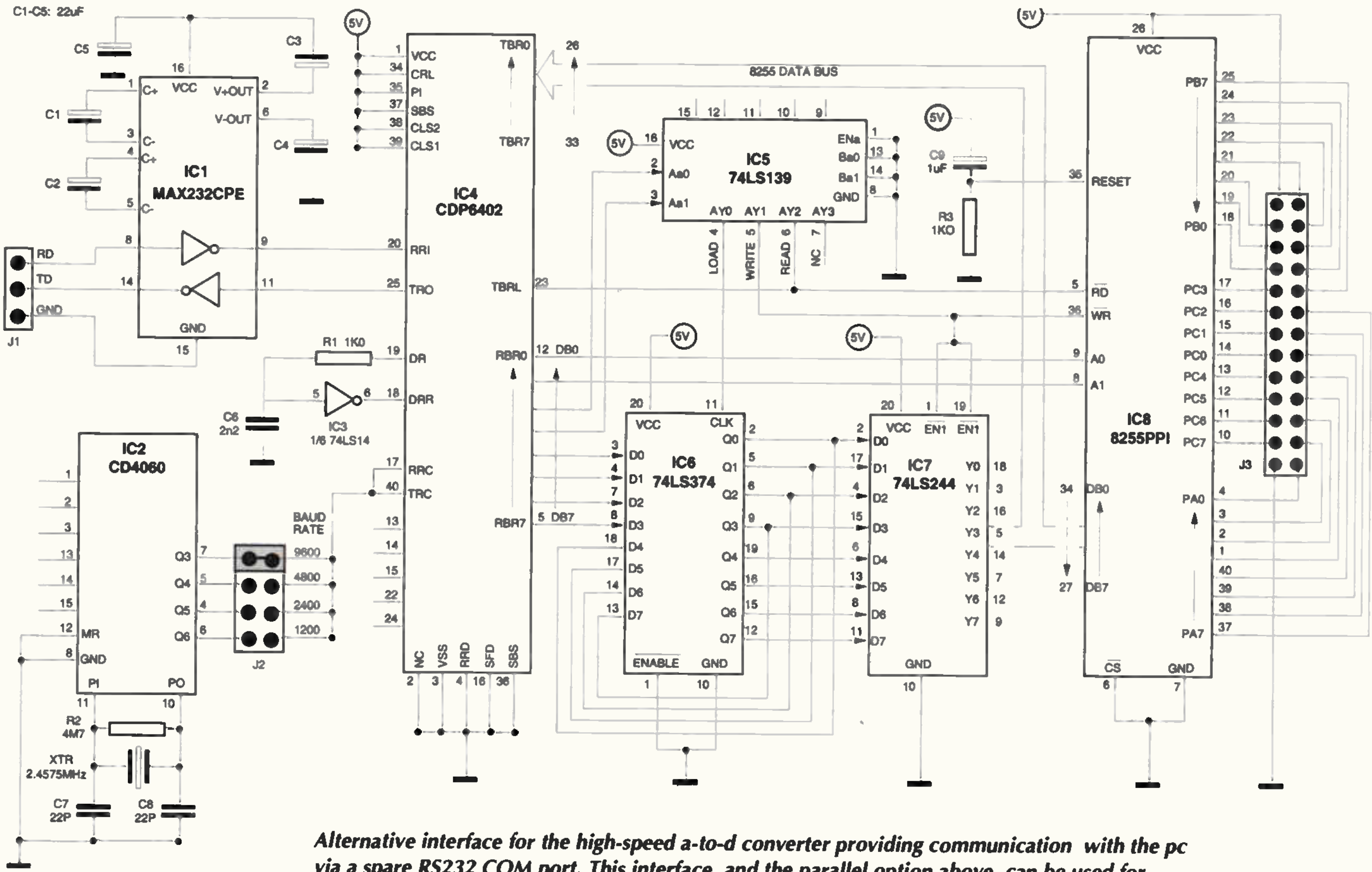
Fig. 6. Timing of the counters that control filling of the flash converter's data buffer.

Fig. 7. Signal conditioning may be needed to convert the real-world analogue input into a signal suitable for the flash converter. On the left is an attenuator converting a bipolar ac signal is into a unipolar one; R_1 controls amplitude, R_2 controls voltage shift. On the right is a CA3140 amplifier for small signals with





This interface, allowing real-world interfacing via the pc's printer port, is suitable for transferring information from the high-speed a-to-d converter.



Alternative interface for the high-speed a-to-d converter providing communication with the pc via a spare RS232 COM port. This interface, and the parallel option above, can be used for general purpose digital i/o.

The timing sequence is as follows. On receiving a low-to-high reset signal from the i/o card, A_{0-15} from the *74LS393*s go low. This sends SEL on IC_2 and /CE on IC_3 both low, Figs 5 and 6. Conversion data appears on the data lines of IC_3. This causes A inputs to feed through to the Y outputs of IC_2.

The system clock connects to the clock pin of counter IC_4. At the high-to-low transition of the system clock, the counter is incremented, Fig. 5. The inverted system clock is fed to IC_3 and to /WR of IC_6. At the high-to-low transition of this signal, IC_6 is set to write mode and at the low-to-high transition, IC_3 is triggered to start an a-to-d conversion. At the same time the data presented on the data bus – which is the previously converted data – is latched into IC_6.

This procedure is repeated until the 32K data buffer is full. At that moment, a further clock pulse to IC_4 makes A_{15} high and A_{0-14} low. Now, SEL for IC_2 and /CE for IC_3 both become high.

At IC_2, CLK2, is issued by the i/o board, is connected to the clock pin of IC_4. Because /CE on IC_3 is high, its output lines are in high impedance state. The computer begins to read data from the data buffer. After reading the 32Kbyte data, A_{15} becomes low. This starts another cycle of data conversion. Reading can be terminated at any time, if the full 32Kbyte data are not necessary. A new cycle of data acquisition can start at any time by issuing a reset signal from the i/o card.

Signal conditioning circuits are needed to convert input voltages to the voltage required by the a-to-d converter. **Figure 7** shows some circuit ideas. Figure **7a)** is a voltage attenuation and shift circuit and is used for signals having higher amplitudes than the reference voltage. Figure **7b)** shows an amplifier for small signals.

Implementing the design

The complete system can be constructed on three single-sided pcb boards: the i/o board, the a-to-d converter board and the data buffer/control board, Fig. 1. Once constructed, the i/o card can also be used as a general purpose i/o for other applications.

Two general purpose interfacing cards, **Figs 8, 9** could be used for the data acquisition card. One operates via pc's printer port, the other via a COM port.

Both cards incorporate an industrial standard *8255* programmable peripheral interface chip for port expansion. This chip provides 24 i/o lines. They are organised into four groups: port A and B are each eight bits and port C is divided into upper and lower four-bit nibbles, providing the final eight bits.

Each group can be configured as an input port or an output port. The use of i/o cards allows easy interfacing without opening the case of the computer. Bear in mind however that the data transfer rate of the two cards is different. The Centronics i/o card has a very fast data transfer rate, while the RS232 option is rather slow. In order to transfer the 32Kbyte of data from the data buffer to the computer, the parallel card takes several second whereas the RS232 card needs several minutes.

In most cases, however, not all the data are needed to be transferred into the computer. This reduces the data transfer time. ■

Technical support

The 8MHz data acquisition board, the Centronics i/o card and the RS232 i/o card are available in kit and assembled form from the author with the TP6 source code and executable file of the software. Please direct your enquiry to Dr Pei An, 11 Sandpiper Driver, Stockport, Manchester SK3 8UL, U.K. Tel/Fax: +44-(0)161-477-9583.

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HP3580A 5Hz – 50KHz ANZ – £750 – £1000.
HP3582A .02Hz to 25.6KHz – £2k.
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HP Mixers are available for the above ANZ's to 40GHz
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TEK 492 – 50KHz – 18GHz Opt 1+2+3 – £4.5k.
TEK 492P – 50KHz – 21 GHz Opt 1+2+3 – £5k.
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TEK 496P 1KHz–1.8GHz – £4k.
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TEK 7L12 – 100KHz–1800Mc/s – £1000.
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TEK 491 10Mc/s–12.4GHzs–40GHzs – £750. 12.4Ghzs–40Ghzs with Mixers.
Tektronix Mixers are available for above ANZ to 60GHzs
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HP8673D Signal Generator .05–26.5GHz – £20k.
Systron Donner 1618B Microwave AM FM Synthesizer 50Mc/s 2–18GHzs
R&S SWP Sweep Generator Synthesizer AM FM 4–2500Mc/s – £3.5k.
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HP3717A 70Mc/s Modulator – Demodulator – £500.
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HP6002A Power Unit 0–5V 0–10A 200W.
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HP4275A Multi Frequency L.C.R. Meter.
HP3779A Primary Multiplex Analyser.
HP3779C Primary Multiplex Analyser.
HP8150A Optical Signal Source.
HP1630G Logic Analyser.
HP5316A Universal Counter A+B.
HP5335A Universal Counter A+B+C.
HP59501B Isolated Power Supply Programmer.
HP8901A Modulation Meter AM – FM – also 8901B.
HP5370A Universal Time Interval Counter.
Marconi TF2370 – 30Hz–110Mc/s 75OHM Output (2 BNC Sockets+Resistor for 50OHM MOD with Marconi MOD Sheet supplied – £650.
Marconi TF2370 30Hz–110Mc/s 50 ohm Output – £750.
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Marconi TF2370 as above but late type Brown Case – £1000.
Marconi TF2374 Zero Loss Probe – £200.
Marconi TF2440 Microwave Counter – 20GHz – £1500.
Marconi TF2442 Microwave Counter – 26.5GHz – £2k..
Marconi TF2305 Modulation Meter – £2.3k.
Racal/Dana 2101 Microwave Counter – 10Hz–20GHz – £2k.
Racal/Dana 1250–1261 Universal Switch Controller + 200Mc/s PI Cards.
Racal/Dana 9303 True RMS Levelmeter+Head – £450. IFFE – £500.
TEKA6902A also A6902B Isolator – £300–£400.
TEK 1240 Logic Analyser – £400.
TEK FG5010 Programmable Function Generator 20Mc/s – £600.
TEK2465A 350Mc/s Oscilloscope – £2.5k + probes – £150 each.
TEK CT-5 High Current Transformer Probe – £250.
TEK J16 Digital Photometer + J6523–2 Luminance Probe – £300.
TEK J16 Digital Photometer + J6503 Luminance Probe – £250.
ROTEK 320 Calibrator + 350 High Current Adaptor AC–DC – £500.
FLUKE 5102B AC–DC Calibrator – £4k.
FLUKE 1120A IEEE – 488 Translator – £250.
Tinsley Standard Cell Battery 5644B – £500.
Tinsley Transportable Voltage Reference – £500.
FLUKE Y5020 Current Shunt – £150.
HP745A+746A AC Calibrator – £600.
HP8080A MF + 8091A 1GHz Rate Generator + 8092A Delay Generator + Two 8093A 1GHz Amps + 15400A – £800.
HP54200A Digitizing Oscilloscope.
HP11729B Carrier Noise Test Set .01–18GHz – LEF – £2000.
HP3311A Function Generator – £300.
Marconi TF2008 – AM-FM signal generator – also sweeper – 10Kc/s – 510Mc/s – from £250 – tested to £400 as new with manual – probe kit in wooden carrying box.
HP Frequency comb generator type 8406 – £400.
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HP Sweep Oscillators type 8690 A & B + plug-ins from 10Mc/s to 18GHz also 18-40GHz. P.O.R..
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HP Amplifier type 8447A – 1-400Mc/s £200 – HP8447A Dual – £300.
HP Frequency Counter type 5340A – 18GHz £1000 – rear output £800.
HP 8410 – A – B – C Network Analyzer 110Mc/s to 12GHz or 18GHz – plus most other units and displays used in this set-up – 8411a – 8412 – 8413 – 8414 – 8418 – 8740 – 8741 – 8742 – 8743 – 8746 – 8650. From £1000.
Racal/Dana 9301A – 9302 RF Millivoltmeter – 1.5-2GHz – £250-£400.
Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
Marconi RCL Bridge type TF2700 – £150.
Marconi/Saunders Signal Sources type – 6058B – 6070A – 6055A – 6059A – 6057A – 6056 – £250-£350. 400Mc/s to 18GHz.
Marconi TF1245 Circuit Magnification meter + 1246 & 1247 Oscillators – £100-£300.
Marconi microwave 6600A sweep osc., mainframe with 6650 PI – 18-26.5GHz or 6651 PI – 26.5-40GHz – £1000 or PI only £600. MF only £250.
Marconi distortion meter type TF2331 – £150. TF2331A – £200.

Tektronix Plug-Ins 7A13 – 7A14 – 7A18 – 7A24 – 7A26 – 7A11 – 7M11 – 7S11 – 7D10 – 7S12 – S1 – S2 – S6 – S52 – PG506 – SC504 – SG502 – SG503 – SG504 – DC503 –DC508 – DD501 – WR501 – DM501A – FG501A – TG501 – PG502 – DC505A – FG504 – 7B80 + 85–7B92A
Gould J3B test oscillator + manual – £150.
Tektronix Mainframes – 7603 – 7623A – 7613 – 7704A – 7844 – 7904 – TM501 – TM503 – TM506 – 7904A – 7834 – 7623 – 7633.
Marconi 6155A Signal Source – 1 to 2GHz – LED readout – £400.
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Marconi TF2163S attenuator – 1GHz. £200.
Farnell power unit H60/50 – £400 tested. H60/25 – £250.
Racal/Dana 9300 RMS voltmeter – £250.
HP 8750A storage normalizer – £400 with lead + S.A or N,A Interface.
Marconi TF2330 – or TF2330A wave analysers – £100-£150.
Tektronix – 7S14 – 7T11 – 7S12 – S1 – S2 – S39 – S47 – S51 – S52 – S53 – 7M11.
Marconi mod meters type TF2304 – £250.
HP 5065A rubidrum vapour FX standard – £1.5k.
Systron Donner counter type 6054B – 20Mc/s – 24GHz – LED readout – £1k.
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HP signal generators type 626 – 628 – frequency 10GHz – 21GHz.
HP 432A – 435A or B – 436A – power meters + powerheads – Mc/s – 40GHz – £200-£1000.
Bradley oscilloscope calibrator type 192 – £600.
HP8614A signal generator 800Mc/s – 2.4GHz, new colour £400.
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HP 8660 A-B-C syn S/G. AM + FM + 10Kc/s to 110Mc/s PI – 1Mc/s to 1300Mc/s – 1Mc/s to 2600Mc/s – £500-£2000.
HP 8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 – £800-£1250.
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HP 3437A System voltmeter – £300.
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HP 5370A Universal time interval counter – £450.
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HP 3782B Error detector (bell) – £300.
HP 3785A Jitter generator + receiver – £750-£1k.
HP 8006A Word generator – £100-£150.
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HP 59401A Bus system analyser – £350.
HP 59500A Multiprogrammer HP – IB – £300.
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S.A. Spectral Dynamics SD345 spectrascope 111 – LF ANZ – £1500.
Tektronix R7912 Transient waveform digitizer – programmable – £400.
Tektronix TR503 + TM503 tracking generator 0.1 – 1.8GHz – £1k – or TR502.
Tektronix 576 Curve tracer + adaptors – £900.
Tektronix 577 Curve tracer + adaptors – £900.
Tektronix 1502/1503 TDR cable test set – £1000.
Tektronix AM503 Current probe + TM501 m/frame – £1000.
Tektronix SC501 – SC502 – SC503 – SC504 oscilloscopes – £75-£350.
Tektronix 465 – 465B – 475 – 2213A – 2215 – 2225 – 2235 – 2245 – 2246 – £250-£1000.
Kikusui 100Mc/s Oscilloscope COS6100M – £350.
Nicolet 3091 LF oscilloscope – £400.
Racal 1991 – 1992 – 1988 – 1300Mc/s counters – £500-£900.
Fluke 80K-40 High voltage probe in case – BN – £100.
Racal Recorders – Store 4 – 4D – 7 – 14 channels in stock – £250 – £500.
Racal Store Horse Recorder & control – £400-£750 Tested.
EIP 545 microwave18GHz counter – £1200.
Fluke 510A AC ref standard – 400Hz – £200.
Fluke 355A DC voltage standard – £300.
Wiltron 610D Sweep Generator + 6124C PI – 4 – 8GHz – £400.
Wiltron 610D Sweep Generator + 61084D PI – 1Mc/s – 1500Mc/s – £500.
Time Electronics 9814 Voltage calibrator – £750.
Time Electronics 9811 Programmable resistance – £600.
Time Electronics 2004 D.C. voltage standard – £1000.
HP 8699B Sweep PI YIG oscillator .01 – 4GHz – £300. 8690B MF – £250. Both £500.
Schlumberger 1250 Frequency response ANZ – £1500.
Dummy Loads & power att up to 2.5 kilowatts FX up to 18GHz – microwave parts new and ex equipt – relays – attenuators – switches – waveguides – Yigs – SMA –APC7 plugs – adaptors.
B&K Items in stock – ask for list.
W&G Items in stock – ask for list.
Power Supplies Heavy duty + bench in stock – Farnell – HP – Weir – Thurlby – Racal etc. Ask for list.

ITEMS BOUGHT FROM HM GOVERNMENT BEING SURPLUS. PRICE IS EX WORKS. SAE FOR ENQUIRIES. PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEMS, AVAILABILITY OR PRICE CHANGE. VAT AND CARRIAGE EXTRA

ITEMS MARKED TESTED HAVE 30 DAY WARRANTY. WANTED: TEST EQUIPMENT–VALVES–PLUGS AND SOCKETS–SYNCROS–TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No: (01274) 684007. Fax: 651160

CIRCLE NO. 140 ON REPLY CARD

NEW PRODUCTS CLASSIFIED

Please quote *"Electronics World"* when seeking further information

ACTIVE

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

Micropower a-to-d. Sipex's 12-bit, sampling analogue-to-digital converter, the *SP8538*, is meant mainly for use in battery-powered equipment and battery monitoring. It operates at up to 25kHz and it provides data transfer to a host on a three-wire serial bus, sampling 12 bits of data in 40µs at 5V. Voltage rail needed is 3-5V, at a current determined by clock rate: at 5V, 250µA at 40µs down to 6.25µA at 1.6ms. Input is programmed for two-channel, single-ended or fully differential. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Discrete active devices

Uhf power fet. *MHW2821-1/2* by Motorola are 806-950MHz power amplifiers in the laterally diffused mos technique, designed for 12.5V working in industrial and commercial fm equipment. Rf power input is ≥250mW (2821-1) or ≥300mW, rf output being 20W (2821-1) or 18W. I/o impedances are 50Ω. Motorola. Fax, 01354 688248.

Microprocessors and controllers

PowerPC processor. Motorola introduces the *MPC801*, an embedded, 32-bit, 40MHz *PowerPC* microprocessor for general-purpose use, centred on consumer communications, and combines the *PowerPC* core with extra peripherals for that purpose. For example, Mitsubishi's *DiamondWeb* television is converted into a web browser by the *MPC801*, which is provided with serial connections for video, audio and monitor facilities. Motorola. Fax, 01354 688248.

Mixed-signal ICs

One-chip multimeter. New Japan Radio's digital multimeter chip has a 20sample/s analogue-to-digital converter, a 42-segment bar display and provides most of the functions now found in multimeters, including autoranging and data hold. It also carries direct drivers for piezo buzzers and has an RS232C interface. As well as the usual facilities, other functions include measurement of rev/min, temperature, battery life, true rms and capacitance. Young-ECC Electronics. Tel., 01628 810727.

Motors and drivers

Stepping motor. *DSMH* series stepping motors by Densitron can be used to replace existing motors on a drop-in basis but, by virtue of a new lamination design allowing greater flux flow at a larger radius, generate higher torque than the older designs. Efficiency is higher, noise is lower and vibration is reduced. Densitron Perdix. Tel., 01959 700100; fax, 01959 700300.

Optical devices

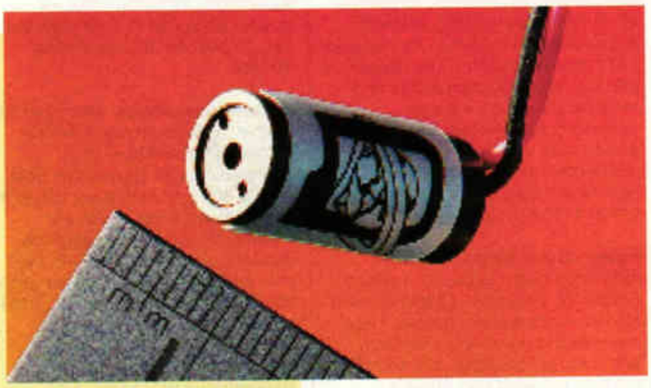
S-m opto-isolators. Isocom Components can supply direct, but surface-mounted, equivalents to any standard opto-isolator in the *IL200* series. All these devices are in SOIC packages and consist of a gallium arsenide infrared led and a silicon n-p-n phototransistor, isolated to 2500V rms. Isocom Components Ltd. Tel., 01429 863609; fax, 01429 863581.

Oscillators

Frequency synthesiser. Analog's *AD9850* is a digitally programmed cmos synthesiser with an a-to-d converter and comparator, usable as a numerically controlled oscillator or as a clock generator agile in frequency and phase for frequency-hopping, spread-spectrum or digital phase modulation. The nco is a 32-bit tuning, 125MHz oscillator with a 42MHz tuning range, the whole dissipating 280mW from 3.3V. Output sine wave has a spurious-free dynamic range of over 50dB at 42MHz and there is also a pulse output at one-third the frequency of the reference clock. Frequency and/or phase are programmable for up to 23 million phase shifts per second. Analog Devices Ltd. Tel., 01932 266000; fax, 01932 247401.

Programmable controllers

Temperature controllers. Cal Controls has a low-voltage version of its miniature *Model 3200* temperature controller, which is designed to cope with the European Low-Voltage Directive. These 1/32 DIN 12V or 24V versions operate from 9-40V dc or 8-30V ac supplies and provide a control stability of ±0.15%, resolution being switchable between 1 and 0.1. Input is selectable from any one of ten thermocouple types, PT100 or five linear analogue ranges over a user-selected span of –200 to 9999. Calibration can be trimmed on site and performance and diagnostics monitors are standard. A second output is provided for heat/cool applications and alarms. Cal Controls Ltd. Tel., 01462 436161; fax, 01462 451801.



Focussing laser. A range of compact visible laser modules by Densitron comprises both fixed-focus and variable types, all being sealed in a brass barrel by epoxy resin. The 635nm *DLM23* is 9mm in diameter and 20mm long, a constant power being internally controlled; peak power is 1mW from 2.4-5V at 25mA. Densitron Perdix. Tel., 01959 700100; fax, 01959 700300.

Power semiconductors

Power mosfets. Rohm n-channel power mosfets are now available from Kestronics. These devices exhibit fast switching and handle a range of voltages, meeting all relevant safety standards. Drain currents up to 10A and V_{dss} to 800V. Kestronics Ltd. Tel., 01727 812222; fax, 01727 811920.

PASSIVE

S-m electrolytics. Electrolytic, surface-mounted capacitors in Samwha's *SC* and *RC* series are 10-20% cheaper than both tantalums and other Eastern electrolytics. Both types are 5.5mm high and range in value from 10-100µF at 6.3V to 0.1-15µF at 50V, the *SC* type also going to 10-150µF at 4V. Samwha Electric UK. Tel. & fax, 01344 427070.

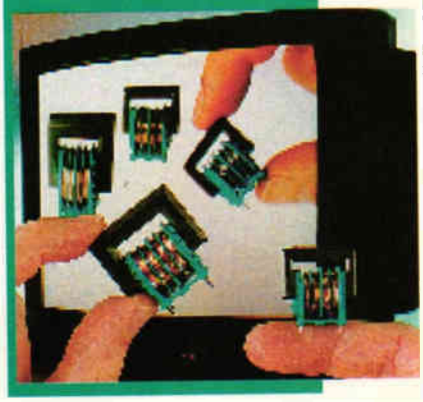
Chip coils. *LQN21A* series air-cored chip coils by Murata are wound on alumina and are for use at high frequencies, having inductances from 3.3µH to 220µH and measuring 2 by 1.5 by 1.78mm. They will cope with both flow and reflow soldering and come on tape for automatic placing. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Noise suppressors. Toshiba Amobeads are amorphous magnetic noise suppressors designed to take single-turn windings, allowing them to be placed over component leads and take up no further board space. They suppress noise due to zero-crossing current by means of a non-dissipative process and losses are smaller than found in ferrites or *RC* snubbers. BFI IBEXSA Electronics Ltd. Tel., 01622 882467; fax, 01622 882469.

Connectors and cabling

Power jacks. Molex has added a

D-core chokes. Siemens offers a new range of D-core chokes to suppress electromagnetic interference in switched-mode power supplies. They are rated at 3.3-47mH at 0.4-4.6A and can be dismantled and used again. Features of D-core chokes are small magnetic scatter field, good rf properties and small footprint. These chokes are also highly reproducible. Siemens plc. Tel., 01344 396685; fax, 01344 396665.



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family of power jacks to the RJ45 range of connectors. For improved insulation between pairs, contacts are only placed in positions 1, 2, 7 and 8 of the eight-way housing. Versions are available in top-entry, right-angled and bottom-entry form. The design provides esd protection to 5kV and removes the need for surge protectors, also avoiding damage when 4-way telephone plugs are accidentally inserted into the power jack. Molex Electronics Ltd. Tel., 01420 477070; fax, 01420 478185.

Power socket strips. Two rack-mounting power-distribution units by Bulgin, the *PMD503/01A* and *02A* are for 19in racks and enclosures. They are meant to be mounted vertically and both hold six EN60 320 power sockets, provided with Bulgin's shutter mechanism in which the earth pin of the mating socket blanks off live and neutral apertures when not in use. The *01A* version has retaining clips to hold the plugs in place. Both types conform to all relevant standards, are fused at 10A and rated for 250V ac, have a neon indicator and 2m of cable fitted with a choice of plug. The units cannot be removed from the rack without special tools. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Telephone sockets. A range of modular telephone sockets by GTK are available as shielded and unshielded 4, 6, 8 and 10-way units. They have a standard footprint, with side or top entry and in low-profile or harmonica form. Sockets are in glass-filled polymer and contacts plated in gold over nickel. There is also a range of mating plugs and cabling assemblies, including those for custom applications. GTK (UK) Ltd. Tel., 01344 304123; fax, 01344 301414.

Miniature coax. connectors. Transradio has the *MMX Series* of very small surface-mounted coaxial connectors providing very low vswr and insertion loss and good shielding. The connectors take the form of a 6.8mm-high s-m receptacle and a right-angled plug and are suitable, at the moment, for RD316 double-screened 2.6mm cable; connectors for other cables will soon be available. Transradio Ltd. Tel., 0181-997 8880; fax, 0181-997 0116.

Hf cable assemblies. *Microcord SHF* flexible, high-frequency, low-loss cables and assemblies from Transradio for all applications from 40GHz super-hf aerospace use to the commercial market. There are flexibles using foam polyethylene dielectric, a cheaper alternative to ptfe, and an armoured type for use to 26.5GHz. Transradio Ltd. Tel., 0181-997 8880; fax, 0181-997 0116.

Hardware

Networking enclosures. New members of Vero's *Imrak* range of enclosures have been produced with an eye to the needs of network installers. There are three families: 12-47U floor-standing model 1400 is for use as a horizontal breakout cabinet in larger installations; the 12-22U 600, wall-mounted or floor-standing, is meant as a local cable-management closet or as a telecoms cabinet and horizontal breakout cabinet for smaller installations; and the 6-15U wall-mounted 400 is a distribution box or patching cabinet. Vero Electronics Ltd. Tel., 01703 266300; fax, 01703 265126.

Seals. Bulgin's *APM Hexseal* range of environmental seals protect switches, circuit breakers and panel meters from liquids and dust. They are made of silicone rubber and resist salt spray, fungus, sunlight, corona, most acids and oils, do not discolour or crack with time and stay flexible down to a temperature of –62°C. Mountings are moulded in to give a non-peel metal-to-rubber bond, a moulded rib sealing the panel cut-out. The seals withstand pressures of over 1500lb/in^2 external and 15lb/in^2 internal. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Air-conditioning for cabinets. Vero has one of the widest ranges of air conditioners designed to cool electronics enclosures, from 300W to 8kW, running from mains or, for telecoms, –48V dc. Heat exchangers are 16-90/K rated and give a cabinet integrity to IP54, all using R134a refrigerant, and being provided with one of a range of control cards. As well as cooling, 'complete climate control' can be arranged, with adjustments to give rapid cooling, to reduce noise or to keep the temperature within narrow limits. A design consultancy service is on offer. Vero Electronics Ltd. Tel., 01703 266300; fax, 01703 265126.

Clip-on cable ferrites. Fair-Rite ferrite cores and cases are designed to clip round flat ribbon cables for emi suppression, either during manufacture or later. The UL94-V2-rated nylon cases have rows of teeth to grip the cable and centre the case around it. They are produced to take 24/26, 40 and 50-way cables, the largest having an impedance of 60Ω at 25MHz and 215Ω at 100MHz. Cirkit Distribution Ltd. Tel., 01992 444111; fax, 01992 464457.

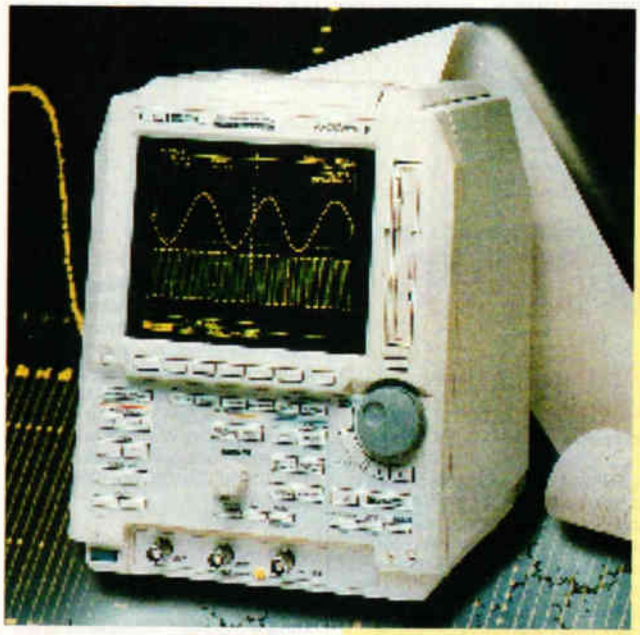
Conductive plastic boxes. TBA ECP has improved its range of plastic storage and packaging boxes, meant for use with devices vulnerable to esd. They now have better catches and a nicer finish and come in sizes from 38 by 38 by 12mm to 230 by 130 by 40mm. Two kinds of conductive foam inserts are available in high or low density – to hold devices in place and to cushion them. TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.

Modular enclosures. From Bernstein Coliprox, the *CS-2000 SL* range of lightweight enclosures for workstations or industrial computers comes in two widths of 55mm and 120mm and can be cut to any length, the die-cast corners allowing any rectangular form to be built to 650mm square as a maximum and providing grooves on the inner faces for mountings. Gaskets give IP 65 emi protection and wiring ducts are provided to take the cable to the support, which is modular and wall or floor mounted. Bernstein Coliprox Ltd. Tel., 01743 441364; fax, 01743 442295.

Test and measurement

Function generator. The Tabor *8020 Series* of 20MHz programmable function generators consists of three models: *8020*, *8021* and *8022*. Basic *8020* functions include sine, square, triangle, positive square, negative square and dc, all being digitally controlled, frequency to within 0.1%. Output amplitude maximum is 15Vpk-pk into 50Ω, short-protected. Sweep facility is settable from 10ms to 100s and any of 30 programmed complete setup states can be stored and recalled and all controls are programmable through an optional GPIB talker/listener interface. *8021*, in addition to the standard functions, provides pulse and ramp, while *8022* has a higher-performance am function with accurate carrier control for rf testing. Thurlby Thandar Instruments, Tel., 01480 412451; fax, 450409.

Recorder modules. Yokogawa's *OR1400* oscillographic recorder is joined by a set of interchangeable signal-conditioning modules. There is an rms converter for frequencies to 10kHz and a frequency input unit to measure rotational speed or speeds of machinery or vehicles. A bridge conditioner for strain gauges handles from 1000 to 20,000 microstrain to 20kHz and there is a monitor for power-line frequencies, accurate to within 0.01Hz. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.



Digital oscilloscope. Yokogawa's *DL1520* lightweight digital oscilloscope has a 200Msample/s maximum sampling speed and input bandwidth of 150MHz. It is unusually shaped, being more vertical than horizontal, and measures 215 (wide) by 268 (high) by 278mm and possesses a 4in diagonal screen. Memory capacity is 20kword in the roll mode and the screen is updated at 60 displays/s. Results can be printed on the optional printer and saved on a 3.5in floppy. Fast Fourier transform harmonic analysis is a standard feature. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

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Literature

Harris digital. Three brochures from Harris describe the company's microprocessors, microcomputers and cmos logic. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Rendar. Rendar has a new catalogue to describe the range of audio, power and communications connectors. New this time are *Quadbloc,* which gives multiple IEC320 outlets with provision for accessories such as fuses, indicators or filters; the *DB2000* electrical services system for offices and factories; and US-UK voltage changers. Rendar Ltd. Tel., 01243 868741; fax, 01243 841486.

DC-to-dc converter guide. Power-One, an American company, has launched a range of dc-to-dc converters in Europe and now offers a publication that explains all about them. The converters cover the 0.75-30W range of output power in single, dual and triple form, all CE marked. Included in the guide are chassis mounting kits and a section on applications. Power-One Europe. Tel., 01769 540744; fax, 01769 540756.

Monitoring and control. CBISS has a new brochure describing its range of standard and custom equipment and systems for process control and environmental monitoring. The company's expertise lies in the sampling and analysis of gases and liquids in stacks, chemical processes, effluents and ambient air, as well as the provision of software for the integration of its equipment into existing systems. CBISS Ltd. Tel., 0151 3431543; fax, 0151 3431847.

Virtual instruments. National Instruments offers its new virtual instrumentation software brochure, which describes the company's software for test and measurement and data analysis. It lists applications and toolkits for NI software including *LabView* graphical programming, *LabWindows/CVI* virtual instrument tools for C/C++ *ComponentWorks ActiveX* controls, *VirtualBench* turnkey instruments, *Measure* for data acquisition and *HiQ* for numerical analysis. National Instruments UK. Tel., 01635 523545; fax, 01635 523154.

Professional components. GEC Plessey Semiconductors' range of linear circuits, frequency synthesisers, dividers and components for uhf remote control are all described in the new *Professional Products Handbook,* which can be obtained from Gothic Crellon. Devices described include the *SP885X* plls for working up to 2.7GHz; *SL3522* and *SL2524* log. amplifiers; and a range of uhf remote-control transmitters and receiver ics. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Materials

Gasket material. TBA ECP has a new low-compression version of its *ECP 802* oriented-wire gasket material. which is a closed-cell, silicone sponge elastomer, perpendicularly impregnated with conductive metal fibres. Density is half that of the original material, which makes compression easier. Wires are bonded to the elastomer and convoluted to reduce 'set'. The material provides emi shielding and is proof against rain and dust to drip-proof and ventilate seals. Uncompressed thicknesses are for 1.6mm to 4.8mm in sizes of 900 by 38mm, with optional peel-off, self-adhesive backing. TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.

Heat-shrink tubing. *Astratite ADM* is a range of electrical grade heat-shrink tubing, by ACAL Auriema, that shrinks to half its inside diameter at 65°C – a temperature supplied by virtually any source such as ir lamps, non-convection ovens, hot water – reducing the risk of component damage. The tube is flexible, operates at 105°C maximum and is not brittle above –70°C. ACAL Auriema Ltd. Tel., 01628 604353; fax, 01628 603730.

Cleaning fluid. *Cleanguard* by Electrolube was designed to clean and polish photocopier glass to prevent paper jams, but is found to be quite as useful for any glass, plastic or rubber equipment. It comes in a pump spray, which is refillable, and you simply spray it on, wipe it off and buff the surface. It does not damage the surface and helps to stop it becoming grubby again. Electrolube Ltd. Tel., 01734 403014/031; fax, 01734 403084.

Conductive coatings. Indium tin oxide transparent conductive coatings used in IVC's *IVINOX* process provide emi/rfi shielding and esd protection to touch-screen groundplanes, display windows and other translucent areas. The resulting groundplane shows a sheet resistivity of 100-200Ω per square and can be applied to toughened glass and soda/lime glass and plastics, curved and flat. Coating thickness relates to the wavelength of light used in the application; for normal displays, 550nm, giving a transmittance on glass of 87% at 20Ω per square. Inco Vacuum Coatings Ltd. Tel., 0121 511 1115; fax, 0121 544 5253.

Production equipment

Component marker. Designed to mark all types of surface-mounted component, Reel-Tech's *LM-6000* laser marker will handle up to 20,000 devices per hour; its handler uses stacked input and output sections taking up to 30 Jedec trays. Set-up and operation, the handler control, laser software and mark editor software are all in a pc interface and there is a optional vision facility to give feedback. Data I/O Ltd. Tel., 0118 9440011; fax, 0118 9448700.

Power supplies

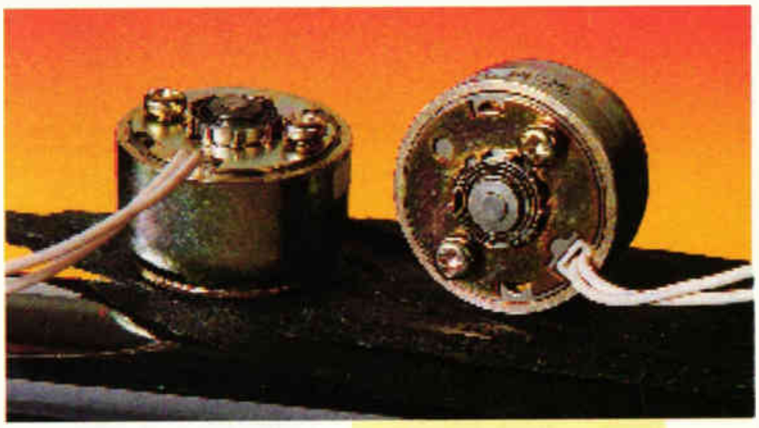
Non-standard voltages. XP's *SRW* series of universal-input power supplies comprises non-standard versions, as well as the standard outputs of 5, 12, 15, 24 and 48V in any combination. Three ranges are available producing output powers of 45W, 65W and 115W in single, dual, triple and quadruple form, positive, negative or floating. All types fit a 1U high enclosure and there are chassis and covers, if required. XP plc. Tel., 01734 845515; fax, 01734 843423.

Unregulated supplies. Conscious of a requirement for unregulated oem supplies conforming to the European safety directive, Calex has introduced the *33000 Series.* The units use no screw top terminals, instead providing cage clamp connectors, which are said to be easier to use and totally safe. Outputs range from 12V, 20A to 48V, 5A and inputs are 115V or 230V. Calex Electronics Ltd. Tel., 01525 373178; fax, 01525 851319

Plug-top dc supply. Arlec's power supply is contained in three-pin mains plug, operating from 230Vac, 50Hz. Output is fully adjustable from the front through a screw hole, which is covered by a nameplate when the adjustment has been made. Output power is 5V at 1.75A to 24V at 0.45A, supplied by way of six different types of plug. Input/output isolation is 4kV and the unit is thermally and current/voltage protected; it conforms to European directives. Chloride Powerline. Tel., 01734 868567; fax, 01734 755172.

Radio communications products

Paging kit. The *AEN 0* tone radio paging system by Blick is meant for use by smaller companies. A kit includes everything necessary to run a small system and has provision for extra pagers; up to 100 pagers per kit. *AEN 0* has four alarm inputs and the pagers have a two-tone bleeper to differentiate between urgent and non-urgent messages. There is also a group call facility. The bleepers run from ordinary AA batteries. Blick plc. Tel., 01793 692401; fax, 01793 615848.



Rotary solenoid. Densitron's rotary solenoids have been redesigned with new pole pieces and case to allow a 15-30% price reduction, mounting by tapped holes rather than threaded studs and a new bearing design all helping in the process, as well as providing a better shaft support. A return spring, dust cover and other shaft configurations are available.
Densitron Perdix. Tel., 01959 700100; fax, 01959 700300.

Switches and relays

Power relay. Matsushita's *DE* power relay is meant for control and domestic use, being a low-cost unit. These relays, which measure 25 by 12.5 by 12mm, can have single or dual contacts, the single type rated at 16A at 250V ac and the dual type at 8A. Contact arrangement can be form A, form B or two form A. A latching version will also be made available. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

ASI-bus microswitch. A version of the *MP31* microswitch is now produced by Microprecision for use in ASI-bus systems, the new version having improved contacts to handle 10-30V dc and under 100mA. It is a form A DIN 41635 unit that can be connected to an ASI module by a directly overmoulded cable terminated by a male jack with screw and locknut. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

Transducers and sensors

Temperature sensors. Miniature, thin-film, platinum temperature sensors by Sensotherm Temperatursensorik GmbH contain a laser-trimmed platinum film on a ceramic substrate with platinum-coated nickel lead-out wires. Resistance values at 0°C of 100Ω, 500Ω and 1000Ω are supplied to IEC751 Class B; tighter tolerances can conform to Class A or better.

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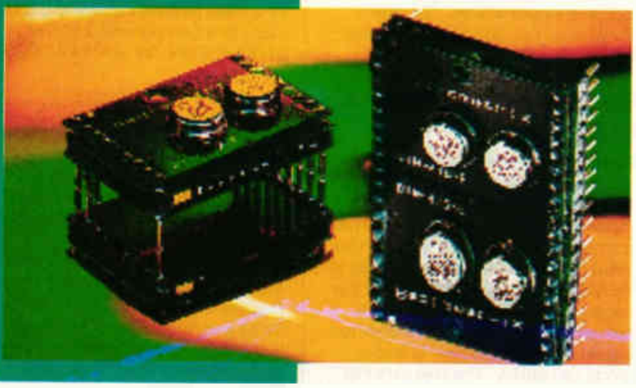
Response time is 0.3s in a stream of water flowing at 1m/s. Willow Technologies Ltd. Tel., 01342 835234; fax, 01342 834306.

Accelerometers. Miniature, light, piezoceramic accelerometers by the Fuji Ceramics Company, the *CR* range of sealed units come in both leaded and 0603 surface-mounting forms. Five sensitivities cover the range 0.77 to 11pC/g. The surface-mounted *SMA KS1 45* operates on X and Z axes at a sensitivity of 1.9mV/g, the SMA11 having a sensitivity of 3-5mV/g. Distributed Micro Technology Ltd. Tel., 01276 33391; fax, 01276 36703.

Quieter ir control. New infrared remote controllers by Sharp, the *GP1U281Q* and *GP1U271R* and associated transmitters *GL537/8* (transmission angles 25° and 13°) offer increased range and an improvement in noise performance over the earlier *IS1U60* series; there is also the *GP1U101X* surface-mounted receiver. Encoding and decoding chips are available to give 12 bits of address/data information for simple, low-cost applications. Hero Electronics Ltd. Tel., 01525 405015; fax, 01525 402383.

Heat flux transducer. Medtherm Schmidt Boelter thermopile heat flux transducers measure the sum of convective and radiant heat in less than 350ms. The sensors generate a millivolt output proportional to the net absorbed heat transfer rate. The devices operate with or without water cooling and there is no upper limit on the gas temperature. Ranges available are 100 to 0.2BTu/ft^2 to an accuracy of better than 3%. Paar Scientific Ltd. Tel., 0181 5408553; fax, 0181 5438727.

Uhf transceiver. With a range of 120m, the Radiometrix *BiM-418-F* and *BiM-433-F* uhf data transceivers take the form of pcb modules measuring 33 by 23 by 10mm. Each has a low-power uhf fm transmitter and superhet receiver with antenna Rx/Tx changeover circuitry. The *418* unit has MPT1340 approval for licence-free use in the UK and the 433 model is approved to ETS 300-220 for European operation at 433.92MHz. Half-duplex data transmission rates up to 40kb/s are achieved. Radiometrix Ltd. Tel., 0181-810 8647; fax, 0181-810 8648.



Alarm systems

Small buzzer. Sonitron has made its smallest buzzer so far, with a diameter of 13mm, meant for use in handheld equipment or anywhere for power saving; it takes only 0.15mA, but still shatters the ear in the approved manner. The *SMA-13* can be surface-mounted, withstanding 175°C four minutes or 225°C for 30s. Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.

COMPUTER

Tough, but portable pc. In the unlikely event of it undergoing a 100g acceleration for 6ms, a test required by MIL-810C, the *FW7600* portable computer will survive, rather better than its user. The computer has a PCMCIA type I, II, III and IV slot, works for two hours on a charge, has three full or six half ISA slots and has a one-piece, rubber-coated, magnesium alloy case. It was designed from scratch to be immune to usage of this kind, rather than being made from 'ruggedised' standard components, even down to the mouse pad. Cpu is a *486DX4-100*, it will take up to 64Mbyte of ram and the screen is a 64 by 480 colour lcd type, with an external vga screen available. If, in addition to the above 100g, it is unfortunate enough to be dunked in water, a sealing kit is on offer. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Data acquisition

24Msample/s analogue VME input. Pentland Systems' *VGD3*, a member of the company's *VGX* data-acquisition family, is claimed to be the fastest of its type, providing eight, 12-bit a-to-d channels sampled simultaneously at 3Msample/s in one VMEbus slot, and even faster with fewer channels. VGX allows VME or VSB to be used, or the data can be transferred to dsps from other companies via *TMS320C4X* comms ports or front-panel data ports. *VxWorks* software drivers and source library routines are provided. Pentland Systems Ltd. Tel., 01506 464666; fax, 01506 463030.

Ethernet data. *EDAS* Ethernet data acquisition system is available in kit form from Intelligent Instrumentation, providing an integrated system for factory automation over a standard, open-architecture network. The kit contains everything needed to configure the EDAS multifunction unit and to start i/o tasks; it supports MMI/SCADA packages, *In Touch, In Control, The Fix* and *Factory View.* The system communicates through a 10Base-T interface and embedded TCP/IP protocol. EDAS 1002E-1 provides 16 single-ended and eight differential 12-bit analogue inputs, two 12-bit analogue outputs and 16 digital i/o channels, the built-in a-to-d converter sampling at 100kHz. Intelligent Instrumentation. Tel., 01923 249596; fax, 01923 226720.

Data communications

Wireless coder/decoder. Microchip's *Keeloq* hopping encoders and single-chip decoders are meant for unidirectional, remote keyless entry applications, in which the only extras needed are the rf circuitry and push-buttons. *HCS360/HCS361* encoders have a 28/32-bit serial number to identify the transmitter and a 64-bit key unique to each device, this being used to generate a secure 32-bit hopping code. Encryption key, serial number and configuration data are held in eeprom, which is read-protected. Both work from 2-6.6V and transmit up to 15 functions. *HCS509/512* decoders provide on-chip eeprom for non-volatile storage of decryption keys and operate from 3-6V. These devices are supported by evaluation, development and programming tools. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

Datacomms board. Concurrent Technologies announces a new Multibus II board, the *TC C12/PEx* Pentium-based communications controller, providing 12 asynchronous RS232C channels in the one slot. The board supports data rates to 38.4kbaud, each channel being accessed via individual RJ45 connectors on the board front panel. Cpu can be either a 133MHz or 100MHz Pentium, with 256Kbyte of fast secondary-level cache and a high-performance dma controller and up to 32Mbyte of dram. Concurrent Technologies Ltd. Tel., 01206 752626; fax, 01206 751116.

Isochronous multiplexer. *MT90710* from Mitel multiplexes up to eight 2.048Mb/s serial telecom links (ST-bus) onto one 20.48Mb/s link for point-to-point data transfer. It connects to standard optical-fibre interfaces to form a noise and radiation free transmission system. In the 84-pin device, there is 15.808Mb/s clear bandwidth support and two 8kb/s and one 32kb/s oversampled signalling channels. Mitel Semiconductor. Tel., 01291 430000; fax, 01291 436389.

Development and evaluation

AMD E86 emulator. *SuperTAP* is the first in a family of emulators for AMD E86 microprocessors, being a third-generation *CodeTAP*, which is code target access probe, to provide high-end, fully featured, portable, in-circuit emulation. It features non-stop emulation, which allows up-loading, trace viewing and trigger modification without stopping the target processor; this and the non-intrusive capability make real-time execution possible. A 386 or compatible host is required, a debugger and linker being supplied; compiler options include C and C++ support. Applied Microsystems Corporation Ltd. Tel., 01296 625462; fax, 01296 623460.

PIC development. Sirius microSystems of Ontario has a development system, the *PIC-MDS*, for the Microchip *PIC* series of low-priced risc microcontrollers. It is a complete development and training aid, consisting of a development board, EPIC programmer, cross-assembler and a detailed manual, which provides step-by-step instruction from simple programming to more advanced procedures such as data logging. The development board is complete with *PIC16C71* and *PIC16C84* controllers, a keypad, lcd, zif socket, led port-state indicators, eprom, 5V and variable power supplies and all connections. Sirius microSystems. Tel., 001 519 886 4462; fax, 001 519 886 4253. Web site http:/www.siriusmicro.com.

Software

Power analysis. Voltech's *VPAS*, which is to say, *Visual Power Analysis Software*, runs on a minimum of 486DX, 4Mbyte and is meant for use with the company's *PM3000A/3300* power analysers, measuring and displaying numerically and graphically analyses of motor drives, lighting ballasts, etc. The software allows complete control by the pc running Windows, which also allows cut-and-paste for reports, printing and on-line help, as well as exporting results in ASCII and CSV for wordprocessing and spreadsheets. Voltech Instruments Ltd. tel., 01235 861173; fax, 01235 861174. ■

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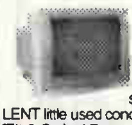

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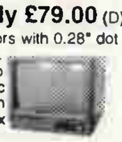

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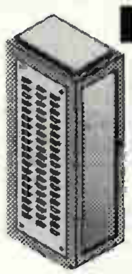

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Paper-thin batteries

Yuasa's new lithium technology can produce power sources thin enough to fit inside a credit card. And PowerFilm – the first product incorporating the new technology – is claimed to be, "the safest lithium primary cell available and – for its size – the highest power density lithium polymer primary cell in commercial production."

Recently, a series of innovative and technical developments have taken place resulting in new opportunities opening up for design engineers looking for more power from less space.

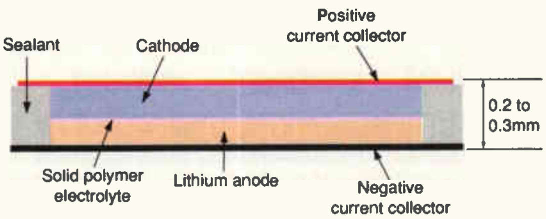
One development that has generated considerable interest around the world is the recent announcement of Yuasa's launch of the world's thinnest Lithium primary cell.

The Yuasa *PowerFilm* is a Lithium 3V cell that can be as thin as 0.2mm and uses solid polymer electrolyte, 'SPE'. Measuring only 29.3mm by 22.3mm, its construction incorporates a lithium anode and a manganese dioxide cathode separated by a solid polymer electrolyte. Anode and cathode are encased between two micro-thin metal foils that also act as an external case and the positive/negative collector.

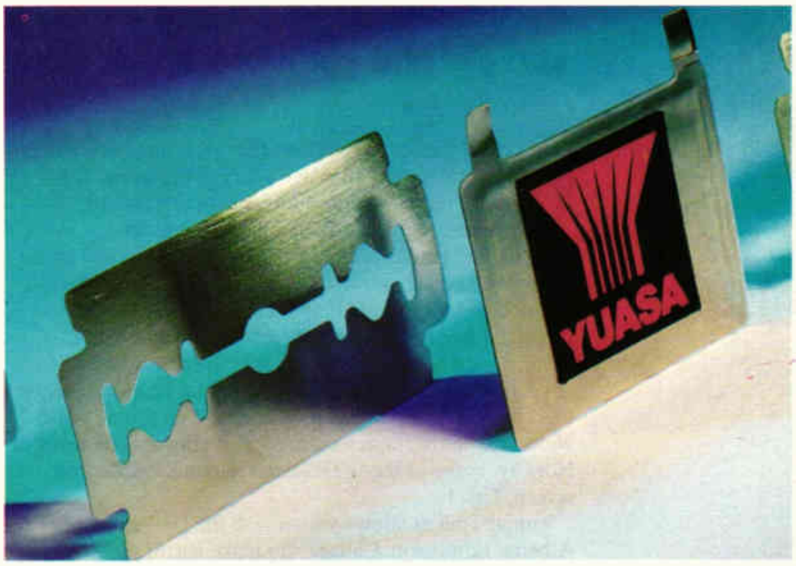
A significant packaging development is the sealing of the outer edges of these collectors using a compound that also provides the electrical insulation between the two polarities of the current collectors. This feature helps make it the safest lithium primary cell available. The Yuasa *PowerFilm* also represents the highest power density SPE lithium primary cell in commercial production.

There is a multitude of existing and emerging applications for these cells. These vary from wrist watches to lap top computers; portable hi-fi to pocket phones; cameras to security devices; electronic keys to smart cards. And each application has a need for batteries in varied shapes, sizes and performance characteristics.

Since the new lithium primary cell can be only 0.2mm thick Yuasa feels that it now offers product designers and electronic engineers new and exciting opportunities to miniaturise their future products and put even more power into less space. The company is also conscious of the fact that this is a Lithium technology battery, and users are wary of this technology. Therefore, PowerFilm has undergone testing to meet – and has passed – the UL standard for safety, UL1642 as user replacable. This makes it the safest lithium polymer cell in production.



In Yuasa's thin, flat cells, lithium ions pass to the cathode as the cell is discharged. A rechargeable version is to be launched by Yuasa early 1997.



Since this new lithium battery technology is safe, and cells can measure down to 0.2mm thick, new application areas could open up.

Another recent development from Yuasa is the introduction of new high capacity nickel-metal-hydride batteries that offer a capacity that is now over twice that of conventional Ni-Cd alternatives. These high energy nickel-metal-hydride batteries achieve excellent high temperature performance by combining a positive electrode made from high-energy-density-nickel with a negative electrode that contains a unique element combined with a $MnNi_5$ based hydrogen storage alloy.

The series of sealed cylindrical secondary nickel-metal hydride batteries offers a choice of models covering capacities 550mAh through to 3500mAh. A typical size is 10.5mm diameter by 43.5mm high for a 550mAh cell.

A number of models are offered in the rechargeable 'Prismatic' series covering 600mAh to 3000mAh capacities. A typical size is 17mm wide by 6.1mm thick by 48.00mm high for the 600mAh model, weighing 17g.

The prismatic construction of these high capacity secondary cells results in outstanding space/power efficiency, making the technology particularly suitable for portable electronic and electrical products. Containing no cadmium, Yuasa's new 1.2V nickel metal hydride batteries are also environmentally friendly. ■

Further information is available from the Sales Manager at Yuasa Battery Sales (UK) Ltd, Hawksworth Industrial Estate, Swindon, Wiltshire. SN2 IEG, tel: 01793 612723 fax: 01793 618862.

Hands-on Internet

Cyril Bateman has found a new locator for *all* World Wide Web servers and yet more circuit simulation software.

I discovered by chance yet another Web directory which amazed me – even after two years of browsing. It is 'Virtual Tourist' and its address is in reference 1.

As its name implies, this site provides tourist information. But its principal task is to identify and locate every Web server world wide. Simply choose the desired location from the world map on its home page to be presented graphically with all servers at that locality.

Since most servers are based in Universities, access to any University's search facility could not be easier. While this site is the easiest way to visit any Web server world-wide, what most impressed me was seeing the resources of Norway, home of the 'FTPSearch' engine, mapped on screen, **Fig. 1**.

Virtual Tourist allows you to visit the University of Alberta, Edmonton, Canada[2], to make use of the establishment's claimed 128 different search engines. This site is a major university, having excellent FTP resources, **Fig. 2**.

Have you wanted to update your Internet software and have failed to fill this need from the many excellent shareware packages that are available using FTP? If so, a visit to 'Strouds' might be of interest. This is a specialist supplier of commercial Winsock applications[3] and is certain to identify much more suitable software, **Fig. 3**.

Infrastructure Corporation's more traditional home page[4] provides two useful and interesting facilities. One is the company's Infrastructure Semiconductor index of manufacturers. This index lists more than fifty semiconductor makers and permits access to the 'Edgar On-Line' corporate and product data for this industry. Secondly, the 'E2W3' home page provides access to a

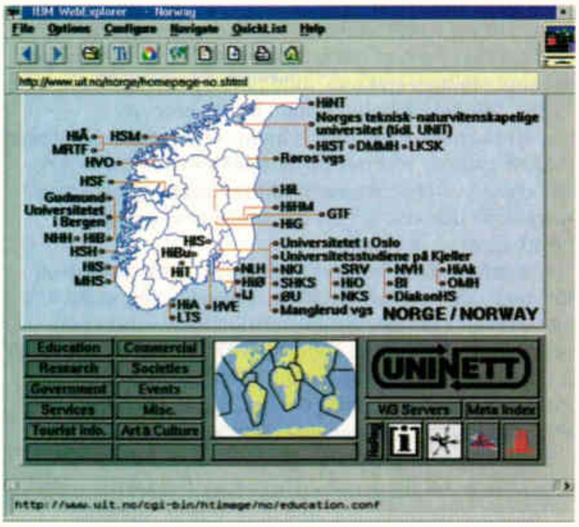


Fig. 1. Norway – home of the excellent 'FTPSearch' engine – provides this Internet Resources Map accessed via 'Vtourist.com'.

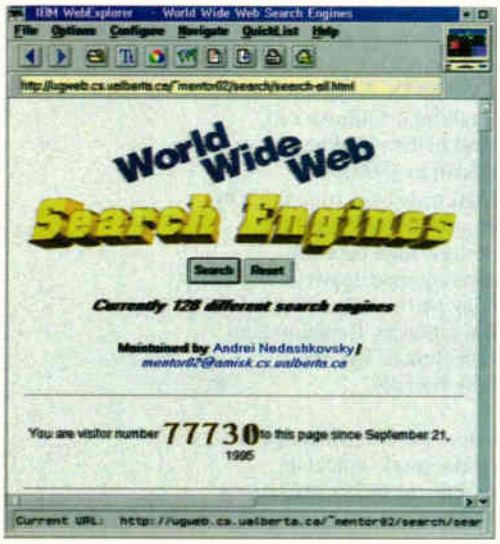


Fig. 2. University of Alberta Search Engine Page provides a different approach to handling large numbers of search needs.

Fig. 3. On-Line shopping for Internet Winsock Application Software – a good one-stop listing of commercially available packages.

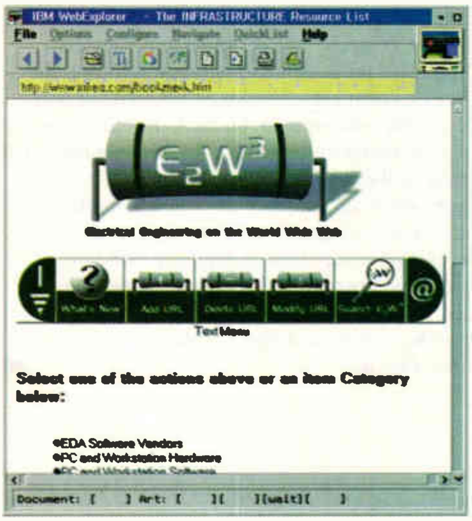


Fig. 4. Electrical Engineering on the World Wide Web – a service for Electronics.
Easy access from simple selection of your needs.

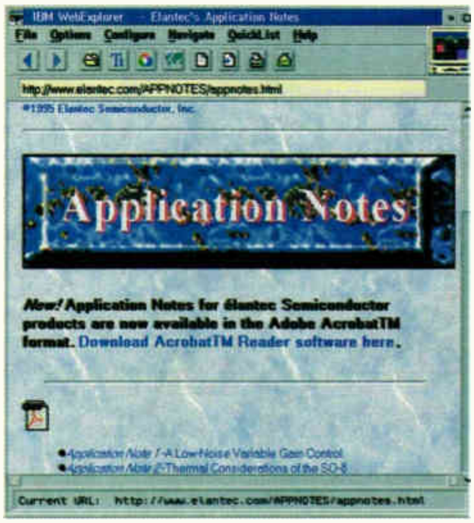


Fig. 5. Elantec supply many Application Notes also Data sheets On-Line.
Simply choose to download in 'PDF' alternately request 'Word' format at bottom of page.

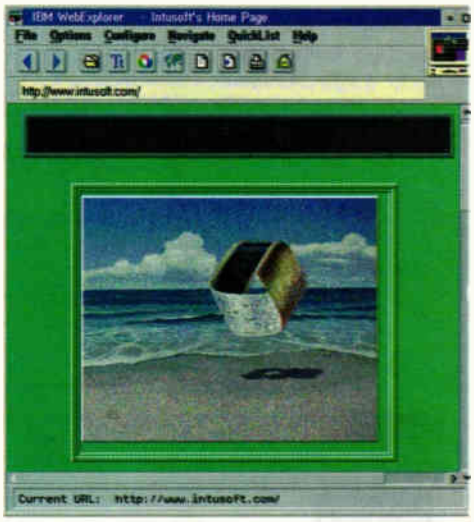


Fig. 6. Intusoft.com Home page – established source of 'Spice' Simulators.
Established 1985 to provide economically priced PC simulation.

wealth of design information, **Fig. 4**.

While HTML remains the basis of all WWW pages and the PDF system highlighted last month looks to be the future for pages needing precise control of appearance of text, tables or drawings, an alternative system RPL is still used by some sites. A freeware RPL reader (Repview.exe) can be downloaded from many sites still using this method.

Simulation software

Following on from the Adobe Acrobat 'PDF' document system discussed last month, Elantec Semiconductors[5] has converted many of its application notes and Data sheets to this format for easy and fast downloading. One Saturday morning, I managed to download four of these in less than six minutes – but printing hard copy took longer.

Like Elantec's semiconductors, many of the company's application notes are a little different. Two, which I found interesting, dealt with generating and using very low distortion megahertz sinewaves, **Fig. 5**.

One early producer of low cost pc based Spice simulators, Intusoft[6] offered its *IsSpice* package for $95 in 1985. It is still available at this price in USA ten years later. The company has been responsible for innovating many of the present day Spice techniques. According to issue 44 of their newsletter, sales have since grown annually around 40%, shipping more than 14,000 Spice packages by that anniversary.

Intusoft's Web page provides download of a 3.7Mbyte demonstration version of the company's medium-priced, current, pc-based 'ICAP/4 Windows' interactive Spice simulator. This is based on the UC Berkeley Spice 3f2 simulator. It has 'B element' behavioural modelling, and now supports frequency-domain simulation using the true capacitor models as proposed by Kemet[7]. Details are in Intusoft's No 44 newsletter and the file 'Caps.Lib' – both available by download, **Fig. 6**.

While most modern Spice based simulators supply extensive libraries of macromodels, these are never sufficient in practice, resulting in the many Internet requests for model data in the Usenet News Groups. Many simulators supply methods for user generation of missing macromodels, given the device data-sheet details.

Unusually, the Macromodel generator included with '*ICAP/4 Windows*', 'SPICEMOD' is available for separate purchase. This package, which is spreadsheet based, produces accurate models usable with any Berkeley SPICE compatible software, and automatically provides sub-circuit definitions when these are needed, for example for power bipolar junction transistors. A demonstration version, downloadable from the Intusoft page, is also included in the *ICAP/4 Windows* demonstration.

Many years ago when needing a dedicated simulator, I mused that it should be possible to make one using spreadsheet software. But on perusing then available spreadsheets I dropped the idea.

Avista Design Systems has a version of the *Spectre* simulation engine[8] running within the 'Microsoft Excel' spreadsheet package, **Fig. 7**. This company was founded by Paul Tuinega, ex Microsim and author of the book 'SPICE a guide to Circuit Simulation – using PSpice'

While less well known, *Spectre* and the market leading *Spice* simulation engines were both developed at UC Berkeley. 'Spectre/XL' from Avista, exploits the OLE capabilities of *Excel* along with its goal-seeking routines to simplify electronic 'what if' calculations by using spreadsheet techniques.

While *Spice* uses time-domain analysis to solve large signal non-linear simulations, *Spectre* uses the frequency-domain 'harmonic-balance' technique. This technique ensures faster and – especially for low distortion rf signal modelling – much more accurate results. It also offers the ability to model using s-parameters and frequency dependent or distributed lossy models.

Frequency dependent components cannot be properly modelled using time-domain techniques. This is the weak

Shop around

Anyone now considering Internet access is advised to ignore any out of date commendations and perform an up to date survey before signing up.

With many new providers, competition is driving prices down and support up. For example my provider recently increased 28.8k modem access to cover 95% of UK with local call access. From 1 October the same provider has substantially reduced the price of the previously expensive unlimited hours rate.

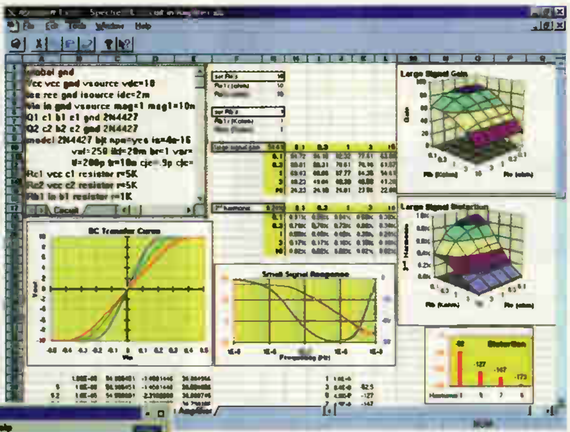
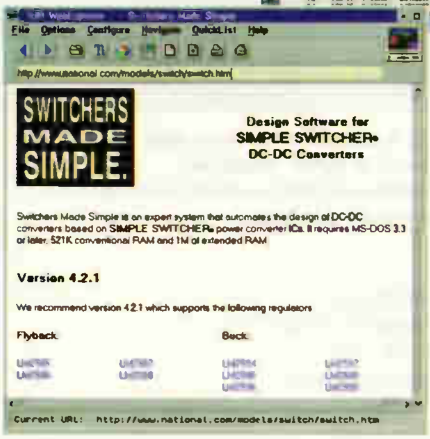


Fig. 7. The 'Avista Corporations' effective use of spreadsheets for design information. This mid-priced system based on 'Spectre' offers visible advantages over 'Spice' systems.

mixer takes seven seconds[10] for example, whereas the equivalent Spice Transient simulation takes 296 seconds.

These techniques also avoid the Spice *bête noir* of non-convergence. Further information on the harmonic balance techniques can be found in the product review reference 10 and in the FAQ on the Avista page.

With the near universal adoption of switched mode power supplies, many designers now are faced with designing for this relatively new technology using their existing Spice simulators. One alternative solution has been provided by National Semiconductors.[11] The company provides a dedicated design solution which can be downloaded, **Fig. 8**. ■



point of the Spice method. However, Fourier transforming from time to frequency domain, modelling by the relevant harmonic frequencies[9], then reverse transforming back to time domain, can provide most realistic results.

Simulation times can be much shorter too. Simulating a quad balanced

Fig. 8. National Semiconductors' 'Switchers Made Simple' says it all. Download this software and get switched on.

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LETTERS

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

Testing dilemma

I refer to the article 'Testing Time for EMC' by Rod Cooper, (*Electronics World*, October 1996).

We have expressed the exact comments made by Mr Cooper to the PLASA Association UK – of which we are international members – and to the Brussels EC offices involved in the introduction of these laws. We firmly believe that these regulations were introduced by politicians in an attempt to curb the import of electronic equipment from the Far East. This has completely backfired on the European Community, as we are all aware that every product imported from this area now clearly bears the EC markings, while many countries such as Greece are completely without any testing facilities for our products.

At a recent meeting here in Greece, attended by EC representatives, we were advised that we had purchased the equipment necessary to set up testing facilities but that there was no suitable building to house the equipment and no trained personnel to operate the system.

After the meeting closed in an uproar, private businessmen considered investing in testing equipment with considerable assistance from the EC. We had been advised by interested parties that they are unable to find insurers for this venture. We considered this quite understandable as, when/if cases do reach the courts, we presume that the manufacturers will automatically charge the company which issued the CE certificate. This could mean vast sums of money involved, if you consider the charges involved in testing equipment.

If the EC considered that these laws and regulations are so important, then national testing centres should have been introduced in each country, all following the same methods.

We are a small family company, employing 25 people, which has been manufacturing professional lighting equipment for the past 20 years. Over the past two years, we have seriously entered the export market. Our main market is China. We were forced to send our units to the UK for testing so that we can export to EC countries, all of which, as you are well aware, is extremely costly.

The EC has advised us of grants for advertising and exhibiting our products abroad and for investing in modern equipment. The only advice that we haven't received is how our products can comply with their laws. The whole business has become a farce.

Ann Baker
SLS Hellas Ltd
Athens
Greece

Two-sided issues

Being on the verge of purchasing a pcb cad software package, I found Rod Cooper's series of articles on the subject to be outstanding. I wait patiently for each issue. His comments on the merits of single-sided boards really hit home. As a retired engineer who has made many small single-sided boards, I appreciate every word he prints.

As I understand it, the main problem with individuals producing double-sided boards is not the two track patterns, but the assumption by software creators that plated-through connections will always be used for vias. This is probably because plated-through connections take up less additional 'real estate'.

Although plated-through connections are possible, as described by David Mason in Q&A (*Electronics World*, November 1996), the scheme he describes is really impractical for most people who, like myself, do not relish the idea of transforming their home into a chemical factory.

Two-sided boards are fine (double-sided pcb stock is more common here than the single foil board), as long as the layout allows for soldering bits of wire between the two sides. One of the beauties of cad is the excellent registration of sides from the printout that enables this technique. This implies soldering pads wherever vias are located. This in turn forces the board area to be greater than otherwise, which often is not a big issue.

The questions are: do the software packages allow one to (a) minimise the number of vias and (b) include soldering pads on both sides of a via?

Would Mr Cooper be able to answer these two questions in regard to the *Ares II* autorouter?

Ralph L Riegler
North York
Ontario M2R 2P8

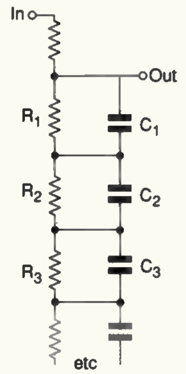
Shifting phase

In your October issue, p790, Alan Scrimgeour asks about wide-band phase shifters. I cannot recall all the data but, around 1955, the American magazine *Electronics* published a circuit for a '7-league oscillator', which was based on a phase shifter covering the whole audio frequency band (see diagram).

The resistor capacitor pairs R_1C_1, R_2C_2, etc, were chosen such that each pair covered an octave. Thus the input-output phase shift was maintained because, as the frequency was changed, only one pair was effective at a time.

I hope Mr Scrimgeour will find this helpful and that he is able to locate the original article.

David H Thomas
Harlow
Essex



Thank you Dr Sandman

I am glad to know that Dr Sandman (October 1996) considers that the Thermal Dynamics articles were well done. I hope he will allow me to explain why his own article of 1982 did not end amplifier history.

A Blameless Class-B amplifier can be confidently expected to generate less than 0.001% thd at 1kHz and less than 0.005% thd at 10kHz, but this is subject to correctly setting and maintaining the quiescent conditions. Setting up is not a process of meticulous trimming – optimising the quiescent takes two seconds, with one eye on the thd residual. However, maintaining its accuracy when junction temperatures may vary over 100°C clearly requires some sort of thermal compensation.

Dr Sandman's letter is only meaningful if he is claiming that his approach can equal or better the performance stated above. However, there appears to be no evidence at all that this is the case. His original article contains no performance figures, and no practical design that could be constructed to test the theory. The figure reproduced with his recent letter is as practical as it gets, and this seems to be driving a 100Ω load rather than 8Ω, which is a very different matter.

If Dr Sandman wishes to prove his point, then surely the least we should expect is the publication of a practical circuit complete with thd plots, etc. Even if it does prove capable of emulating a Blameless amplifier, the requirement for separate amplifiers seems to make it inevitable that the complexity will be greater, and possibly twice as great.

It is worth saying again that the superb linearity of the generic amplifier configuration, subject to certain precautions and minor enhancements, came as rather a surprise. Its performance certainly falls short of perfection – for example, thd deteriorates at load impedances below 8Ω. However, it is not clear that switching to radically different lines of enquiry is appropriate at this stage.

Douglas Self
Idmiston
Herts

Well-damped response

I was sorry to learn that Mr Wright (*Electronics World*, November 1996) does not like arguing in public. If this is so, then issuing personal challenges in a forum of debate like *EW*'s Letters page is not the way to avoid it.

He challenged me to explain an alleged effect, and I put forward the likeliest answer. I couldn't guarantee the answer would match his preconceptions, but apparently this is not the cause of his distress, because the most worrying thing about his letter is that he is complaining about a reply from me that he hasn't even read.

He dismisses "dumping on the loudspeaker" as an explanation for his loudspeaker problems, but I never mentioned damping, which I hope is what he means, in my entire letter. What I did say is that high-resistance loudspeaker cables will add a variation to the room/speaker response due to the frequency-varying load impedance of the loudspeaker.

This seems the likeliest explanation of a real subjective difference, certainly far more likely than magical mystery diodes, which have been unequivocally proven not to exist. Effects on the speaker damping are likely to be negligible as the resistive component affecting this is dominated by the voice-coil resistance, which will be 6-7Ω.

Mr Wright retaliates with some less than friendly comments on my preamplifier design, which are equally at variance with the facts. He claims that the *5532* op-amp has an "unpleasant sonic signature", which presumably means he thinks it sounds wrong in some fashion he can't be bothered to specify. This is a flat untruth, and if Mr Wright knew anything about the internals of mixing consoles he would know that all the top-flight models, from all the well-known manufacturers, use *5532*s almost exclusively. It may be an old IC design, but it is an old, good design, and in practical use it is hard to find anything better.

It is equally wrong to say that budget mixing desks have dropped this IC, for if Mr Wright had studied the subject he would know that *5532* have never appeared in significant numbers at the budget end, because they are more expensive and more power hungry than, say, *TL0725*s. Perhaps Mr Wright knows of a better IC. If so, he seems to have forgotten to mention it.

Similarily, he may find it unbelievable that I (and the rest of the professional audio community) use electrolytic capacitors, but I don't see why. They pass audio quite transparently, given the simplest of precautions, so where is the problem? Perhaps Mr Wright has a better preamp design he is about to publish, so it can be put in the glare of public scrutiny. And perhaps not.
DS

Preamp on sale

I am writing after reading the article on phono preamplifier design by Simon Bateson (*Electronics World*, October 1996, p758).

In the final paragraph, Simon refers to the possibility of using a balanced input for the interface between the cartridge and the preamplifier. I would like to bring to his attention that we have been manufacturing a Balanced Phono Preamplifier for approximately the past five years, the *MCB2*.

As he has suggested, the advantages are significant, most notably in the area of common-mode rejection ratio and thus noise immunity.

M Hudson
HiQ Sound
South Carlton
Lincolnshire

Cable science?

The article on page 939 of the December issue is the worst published by *Wireless World* for at least 50 years.

The magnetic field around a wire is a rectangular hyperbola, not an exponential, as claimed in Fig. 1. Figure 2 fails to illustrate "how electrons are forced toward the skin". Figure 3 survives because no values for frequency are inserted, so the author can pretend that skin effect is relevant at audio frequencies. "Plastic sheath" effects are a nonsense. In Fig. 4, talk about dielectric thickness is nonsense.

The author, attempting to write about electric current in cables, gets away with not even one equation or formula. Is the article a spoof?

Penelope Lyon
Redbourn, Herts

Class-A oops

I have discovered to my embarrassment that I made an error, due, I regret, to my over-hasty copying of Fig. 3 in my 15W Class A amplifier article, (*Electronics World*, September 1996, p685). The earthy return of the negative feedback dc blocking capacitor, C_4, was shown going to the –22V line, rather than, as it should have been shown, connected to the 0V rail.

This has the effect of making the circuit more sensitive to residual 100Hz ripple on the –22V line.

John Linsley-Hood
Taunton
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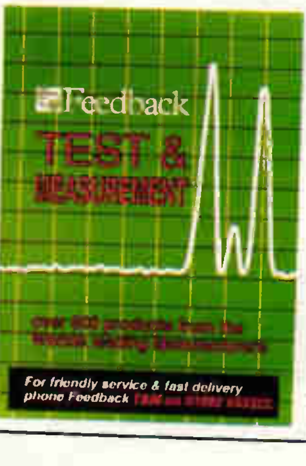

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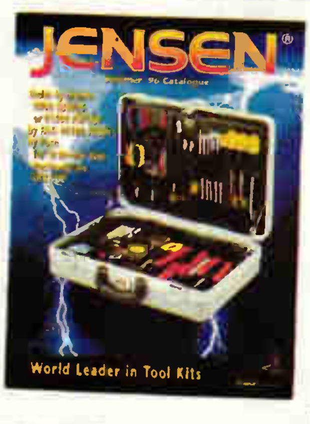

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Flash Code ROM (bytes)	4K	4K	8K	8K	20K	8K	2K	1K
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EEPROM	-	-	-	-	-	2K	-	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
I/O Pins	32	32	32	32	32	32	15	15
[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Watchdog timer	-	-	-		-	YES	-	-
[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Serial UART (full duplex)	YES	YES	YES	YES	YES	YES	YES	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	YES	[illegible]	[illegible]
Analogue comparator	-	-	-	-	-	-	YES	YES
[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]
Package Pins (DIL)	40	40	40	40	40	40	20	20

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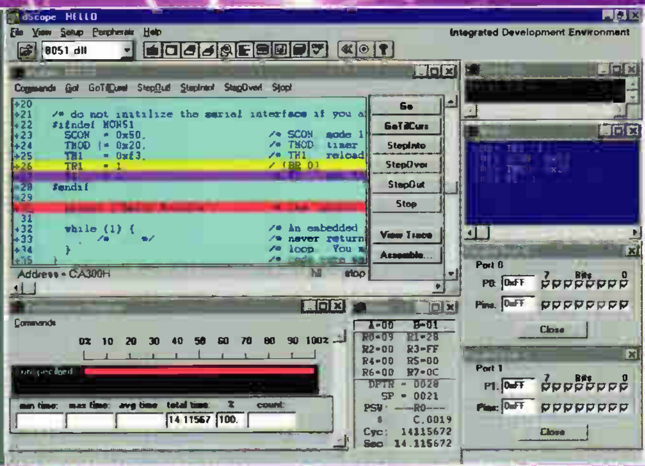

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