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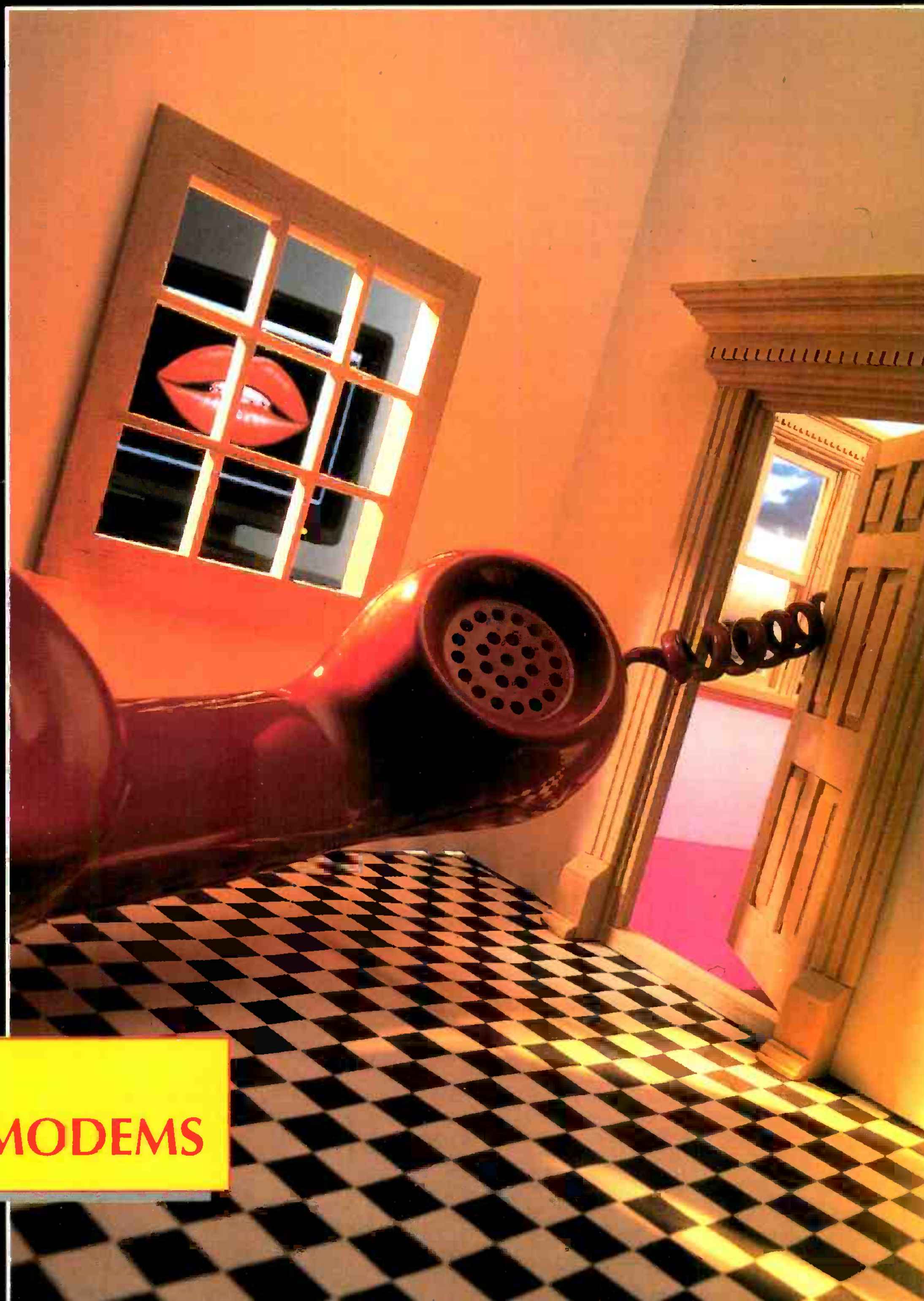

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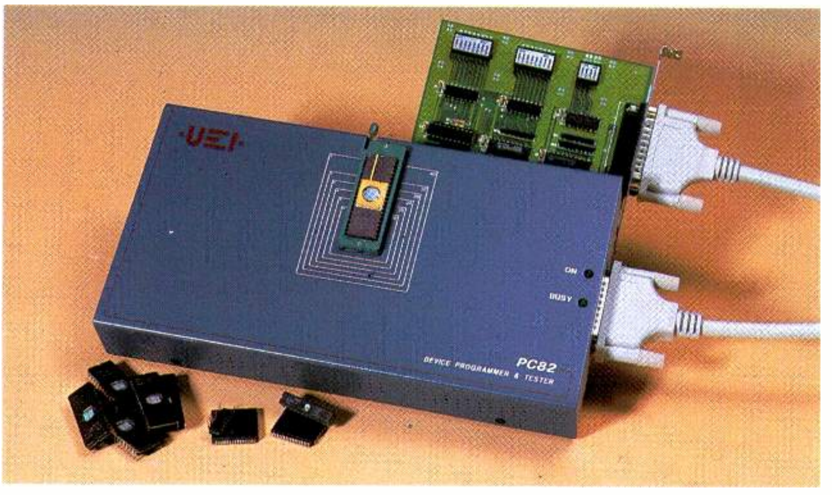

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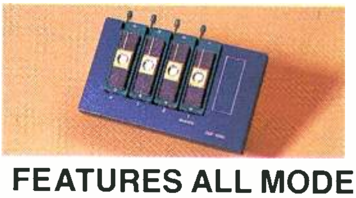

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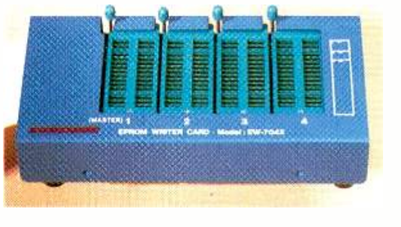

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In next month's issue. Special feature on audio design includes details of a 200W/channel amplifier, a single chip programmable sine wave generator, a design study for brick-wall alias filtering. Plus much more.

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Competing against the State

By the time this magazine appears, the UK will have a new government and the election promises which put it there will be largely forgotten.

The incoming administration should be continually reminded that the UK electronics industry is worth £4000 million in turnover: it resides at the centre of economic recovery and at our future as a successful industrialised country.

There is no corner of industry which it doesn't touch: the car makers use it, the plane makers couldn't fly without it, the utilities need its telemetry, the transport sector requires it for signalling and the finance sector depends on it for computing, etc. To say that it has strategic significance is an understatement.

The Japanese recognise this and organise their government departments accordingly. MITI – Ministry of International Trade and Industry - develops its services in response to the needs of Japanese industry, for instance in co-ordination of complementary activities among competing companies towards strategic goals. Its officials are well schooled in promoting the image of Japanese technology abroad: we seldom read about that country's failures even though they occur just as frequently as ours.

By contrast, the British DTI employs a gaggle of well meaning civil servants, very few of whom will have enjoyed a science based education or any form of industrial experience, who we expect to act competently on behalf of technology based companies. With the best will in the world they would find it difficult to fulfil the kind of co-ordinating role which their Japanese counterparts provide. The best that the DTI can manage is a prescriptive, rigid service which takes little account of the subject in hand.

UK industry suffers greatly from a generally dismissive attitude towards engineering and science. For instance, a telling situation existed in the last parliament whereby the House was unable to find the six MPs necessary to sit on a parliamentary subcommittee dealing with the subject. By contrast committees dealing with accounts, defence and legislation are well subscribed.

This lack of understanding about technology-based industries profoundly affects the way in which they are financed. The free market operates entirely through return upon investment. This leads to a situation where publicly quoted companies have to provide shareholder dividends even when the earnings aren't there to support them, inevitably a frequent occurrence during a deep recession. The alternative is to risk a collapse of the share price with its attendant takeover risks. Companies will cut R&D to the bone to maintain dividend... there are even instances of borrowing to pay the shareholders. The electronics industry lives by research and development: short term cuts will jeopardise future UK based growth across a whole range of related activities.

A demand driven economy also generates its own imperatives. When the City can earn higher interest with greater security by buying into gilts then why should it invest in industry? This leads to an interesting situation. The government issues gilt stock to raise money to support government borrowing. Eventually, it will have to pay back the money plus interest. It usually does this by further borrowing. It sets interest rates and conditions which ensure that gilt issues are fully subscribed placing the government in direct competition with industry for investment capital in a totally unfair contest.

Until the new government acts to reverse this unequal conflict, there can never be substantial industrial renewal together with its possibilities of genuine wealth and opportunity creation.

Frank Ogden

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REGULARS

UPDATE

Non-Intel 386 claims 486 performance

A Texan chip company has come up with a 25MHz 486 type of processor which claims to provide up to twice the performance of the 386SX and 386SL at equal clock frequencies yet retains bus and pin-out compatibility with the original 386 part.

Cyrix, a recent entry to the semiconductor industry, claims its Cx486SLC offers notebook manufacturers an instant upgrade to 486 performance for less than a quarter of the price of an Intel 486 – Cyrix is quoting volume pricing at $119. With its 87SLC co-processor, Cyrix claims a footprint four times smaller than for the Intel 486SX LP/487SX LP combination.

Intel has taken the threat to its business seriously; it has initiated proceedings against Cyrix for patent infringement.

The chip supports 8, 16 and 32-bit data types and operates in real, virtual 8086 and protected modes. Its performance comes from a variable length pipeline combined with a risc-like single cycle execution unit, an on-chip hardware multiplier and integrated instruction and data cache.

Cyrix says that the multi-instruction-per-cycle processor's combination of pipelined execution unit, 16 x 16 hardware multiplier (claimed to be faster than the 486 multiplier) and local cache give the chip its 486-like performance.

Pipelined architecture

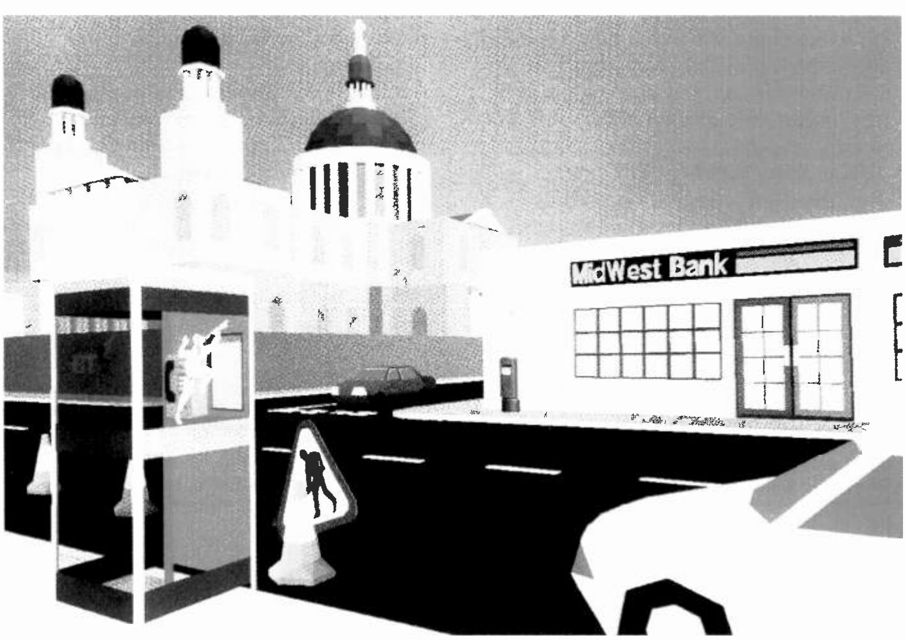
The Cx486SLC execution path consists of four pipelined stages designed with hardware interlocks to permit successive instruction overlap. They are: code fetch; instruction decode; microcode rom access; execution; memory/register file write-back. The 16-byte instruction prefetch queue fetches code in advance and prepares it for decode, helping to minimise overall execution time. The instruction decoder then decodes four bytes of instructions per clock eliminating the need for a queue of decoded instructions.

Sequential instructions are decoded and provided to the microcode rom. Non-sequential operations do not have to wait for a queue of decoded instructions to be flushed and refilled before execution continues. As a result both sequential and non-sequential instruction execution times are minimised.

The chip's write-back stage provides single cycle 32-bit access to the on-chip cache and posts all writes to the cache and system bus using a two-deep write buffer. Posted writes allow the execution unit to proceed with program execution while the bus interface unit actually completes the write cycle.

External memory access takes a minimum of two clock cycles (zero wait states). For cache hits, the Cx486SLC eliminates these two clock cycles by overlapping cache accesses with normal execution pipeline activity. Additional bus bandwidth is gained by presenting instructions and data to the execution pipeline up to 32 bits at a time compared to 16 bits per cycle for an external memory access.

The on-chip cache is a 1Kbyte write-through unified instruction, and data cache and lines are allocated only during memory read cycles. The cache can be configured as direct-mapped or as two-way set associative. The direct-mapped organisation is a single set of 256 four-byte lines.



Virtual reality accident

Police forces could soon be using virtual reality computer programs to help reconstruct road accidents. Events which led up to the incident can be modelled and then viewed from the perspective of a chosen observer, whether a bystander or the driver of any of the vehicles involved.

Buildings and vehicles can be created from scratch or summoned from a library of objects. The system, which runs on a 486 PC, was developed by Aldermaston based Dimension International.

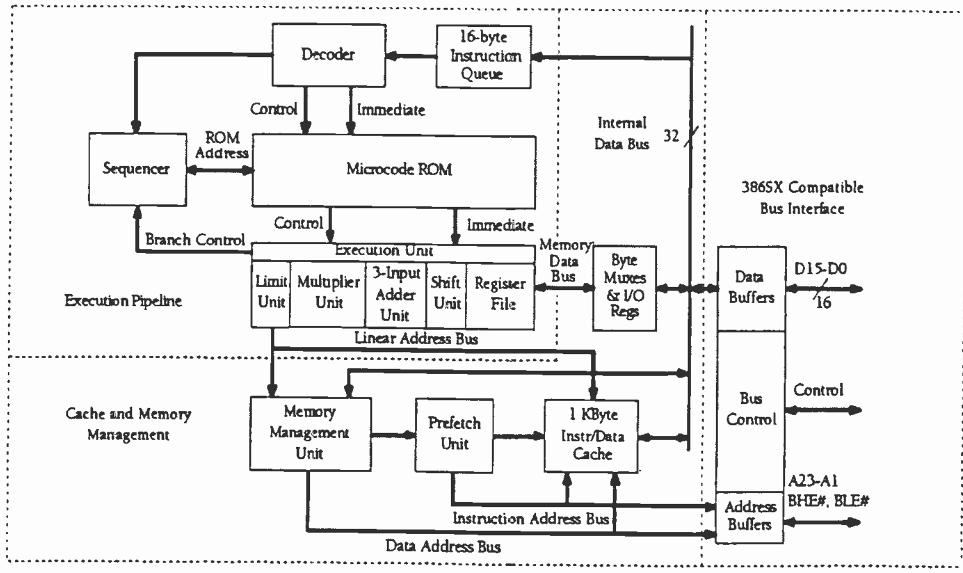
When configured as two-way set associative, the cache organisation consists of two sets of 128 four-byte lines and uses a Least Recently Used replacement algorithm.

Support chips are planned by Oak Technology. One, called OakNote, includes system controller, peripheral controller and VGA controller supporting true colour for photographic-quality images. The other, the Oak486SLC includes system, peripheral and LCD VGA controllers which provide integrated power management.

In suspend mode the Cx486SLC typically draws less than 0.8mA and operates from 5V or 3V power supply. Operating with 3V uses only 30 per cent of the power used when operating with 5V.

Intel has sued Cyrix for four alleged patent infringements. Cyrix claims that by using SGS-Thomson as its foundry – which has a cross-license agreement on the 386 and 486 with Intel – it is fully protected from legal action.

David Manners, *Electronics Weekly.*



386 pin-compatible Cyrix architecture speeds up a PC by a factor of two over a 386 powered machine run at the same clock speed. Extensive use of pipelining accounts for the boost.

Full-motion CD-I moves into the picture

In mid-March, Philips gave the first demonstrations of a CD-I player, decoding full screen, full motion video direct from a 12cm disc, using chips designed to the new MPEG standard (Moving Picture Experts Group of the International Standards Organization). These demonstrations are already creating shock-waves through the industry.

Until the demonstration, few people believed that MPEG full motion could, as Philips had claimed, deliver picture quality as good or better than VHS, and sound quality subjectively as good as 16 bit CD audio. The demonstration, given during the Multimedia and CD-rom Conference in San Francisco, proved that the MPEG standard really can live up to the promises.

Philips had double-sourced chips from Motorola and US company C-Cube as an insurance policy. In the event, both companies delivered on time and Gaston Bastiaens, Director of Philips interactive media systems, now promises CD-I players with MPEG chips in time for Christmas. But Philips has now adopted a dual marketing strategy. Some players will be sold with MPEG chips, and others (like those currently on sale in the US and due in the UK this spring) will be sans-FMV but upgradeable with a plug-in 100 pin cartridge containing the MPEG chips. full motion-capable players and upgrade cartridges are promised in time for Christmas sales, along with the first software to exploit the technology.

Previously Philips had said that CD-I would be launched in Europe only when MPEG chips were ready, and that all European CD-I players would play full motion discs from day one. Adoption of the new dual marketing strategy follows from successful work done at the Philips Interactive Media of America Production Centre in Los Angeles, a joint venture between Polygram and Philips which was set up in 1986 to develop interactive software for CD-I. The new technique so skillfully blends partial screen moving video with a static or animated background, that the seams do not show. Pima believes that many multimedia programmes will be just as effective with partial screen video, so the added cost of full motion production is not justified.

The high production costs of full motion material follow from the fact that although the MPEG decoding chips in the player operate to a fixed standard, the encoding process relies on operator skill. Already a new craft is emerging, conversion of video or film material to MPEG full motion format. Skilled encoding delivers VHS quality. Unskilled, or automated, encoding delivers pictures of very poor quality. There is smear on motion, and break-up into mosaicing after scene change and during sequences where the screen is full of action and there are quite simply not enough digital bits in the data stream to go round.

Prior to the San Francisco conference all demonstrations of the MPEG standard had been sourced from computer simulations, and did not match VHS quality. Demonstrations of MPEG video given by Sony at San Francisco prior to Philips' scheduled showing were very poor. Philips used a video projector to beam excerpts from *the Three Tenors* operatic video recording and the James Bond film *Licence to Kill* onto a large screen. Picture quality was better than VHS and the sound matched CD. This completely re-writes the rules of home video entertainment.

Says Gaston Bastiaens: "I am convinced that 12cm CD-I is the ideal carrier for music videos". Currently record companies must pay $8 to press a 30cm analogue laser video disc and around $3 to duplicate a VHS video tape. But they can press a 12cm CD for 60 US cents. With MPEG coding this can now store over an hour of digital video and audio. Like a CD audio disc the MPEG video disc will play back in any country, regardless of local TV standard. Picture sequences on the disc can be indexed for rapid access, like music tracks from an audio CD. Bastiaens also predicts that film companies will release interactive versions of sections from feature films, for instance a version of *Back to the Future* which lets the

Red faces

Despite the April cover date of the last issue, a couple of errors crept in which were not intentional. Allen Brown's assessment of the Analog Devices ADSP-21020 floating point signal processor was marred by the absence of an architectural diagram. Some unrelated screen shots found their way into the magazine in its place. Analog Devices will be pleased to supply the missing details on 0932-232222. Sincere apologies are due to Allen and anyone else who was confused.

Alasdair Philips' design for a low frequency dosimeter was also flawed. The sensor amplifier diagram on p282 should state C1 as 100nF, and R1 as 180kΩ. Also the captions on the two diagrams were unintentionally transposed.

FO

user select times and places to visit by time travel.

It normally requires a data stream of over 200Mbit/s to convert analogue TV pictures into digital code without any loss of quality.

The existing standards for CD audio and CD-I set a rotational speed for the disc which limits the useable data rate available to around 1.5Mbit/s. So far the CD-I system has only been able to display low resolution, jerky moving video in a window one tenth the size of the screen, with the remainder of the screen displaying a still picture. The action is less jerky if the moving picture is in black-and-white only. The MPEG standard defines a method of digital data compression which reduces the video data rate for a full screen moving colour video display to around 1.2Mbit/s and the stereo sound to around 0.3Mbit/s.

Looking for the difference

Last year the MPEG committee bravely threw out all its previous work on audio coding and set a standard which works in the same way as the Eureka system for digital audio broadcasting and Philips' digital compact cassette. The sound is divided into many narrow frequency bands and the content of each band analysed, to register where loud sounds will mask the perception of quieter sounds of similar frequency. Each band is then coded with only as many digital bits as are necessary to register audible sounds. This reduces the number of bits per second needed for CD quality stereo to around 300kbit/s, one fifth the data rate for conventional audio CD.

The video coder analyses each of the 25 or 30 picture frames a second (25 for Europe, 30 for the US and Japan) and detects where the image content changes from frame to frame. The coder then registers only the differences. This reduces the bit rate by a factor of 200, from over 200Mbit/s to 1.2Mbit/s. To cope with scene changes, where a close-up switches abruptly to a long distance view, the decoder has a memory which stores all incoming frames and compares past, present and future information on picture content.

There are three types of coded picture frame on the disc. Intra or key frames are fully coded to give reference information on the general content of a scene. Predictive and interpolated frames compare the intra frame with one frame backward and one frame forward. These frames contain only difference information. The coded signal coming from the disc interleaves predictive and interpolated frames with one intra reference frame every 15 frames. The decoder stores a series of incoming frames in memory to reconstruct full pictures.

Although the decoding process is fixed, the coding process is flexible and governs the quality of the pictures seen on screen. The coding engineer must run a sequence several times, judging how best to cope with rapid cuts and scenes which contain a lot of action. The trick is to "steal" digital bits from some parts of the picture sequence which are stationary and do not need them, using the freed bits for other parts of the sequence with rapidly changing picture content.

Despite the impressive demonstration at San Francisco, Gaston Bastiaens believes that there is still room for some further improvement in quality at the data rate of 1.2Mbit/s. He argues strongly against waiting for the second MPEG standard, MPEG 2, which will define coding at 6Mbit/s. MPEG 2, still under discussion, relies on a completely new CD standard, with quadrupled recording density. This, in turn, relies on new optics in the player, with incompatibility between new and old discs and players.

The decision to sell two types of CD-I player, with and without MPEG chips, follows Philips success with another development. This lets an existing CD-I player, without MPEG chips, display what appears to be moving video. The trick here is for the production engineer to graft moving video sequences into natural still picture or animated graphics backgrounds, with no visible window round the motion. This is done with a modification of the technology, called Chroma-key, which is already used to blend film or video action with different backgrounds eg to let Superman fly over a city.

An action sequence, for instance a baseball pitcher, samurai warrior, card dealer's hands or animated puppet, is filmed against a background of pure blue or green. The sequence is then superimposed on a scene which contains no colour that matches the original background. With skill the two sequences blend together seamlessly. Without skill the edges of the moving object shimmer. The Philips Interactive Media of America Production Centre in Los Angeles has now developed a technique of disguising this "aliasing effect". The edges are slightly fudged by imposing a range of colour dots which bridges the gap between background and foreground.

The moving video only occupies one tenth of the screen but skilful production grafts the moving foreground into the stationary background, so that the viewer is unaware that the picture is a composite image. The effect is enhanced when the live action actors speak and their words are synchronised with their lip movements.

Gordon Stulberg of PIMA describes this as "putting the video into video games".

Barry Fox

Digital audio broadcasting "most important"

Digital audio broadcasting will be the most important development in broadcasting during the 1990s claims the BBC's Philip Laven. He says that the interference resistant system is "well matched to the public needs while offering significant benefits to broadcasters, the electronics industry and spectrum managers."

The recent Warc conference held at Torremolinos allocated a dab band at 1.5GHz although this will not become available until 2007. In the meantime, broadcasters are looking at the possibilities of using a 7MHz wide channel in band III for four nationwide services; the dab system with its immunity to multipath fades allows national networking using just a single frequency. A conventional FM network requires multiple frequencies for complete coverage to avoid the effects of time delay.

Dab radio receivers will be very different to the traditional analogue counterparts: Europe's semiconductor makers are cooperating under the Jessi programme to develop a two-chip receiver system for the service which the EBU hopes will commence broadcasting by 1995.

Georgia Tech researchers Victor Tripp and Johnson Wang examine a new type of microstrip antenna. The spiral flat-plate provides bandwidths of up to 9:1 in the 2-18GHz frequency range. The circular polarisation makes it suitable for applications such as GPS, wireless lans and direct broadcast satellites. The planar nature of the system makes it eminently suitable for vehicle based use as does its small size – typically 5 to 12cm diameter.

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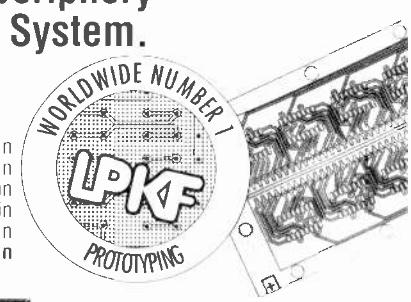

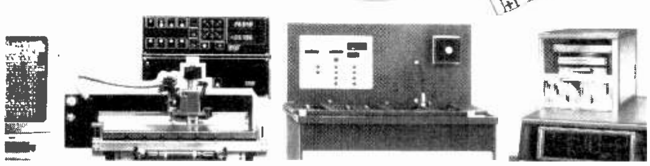

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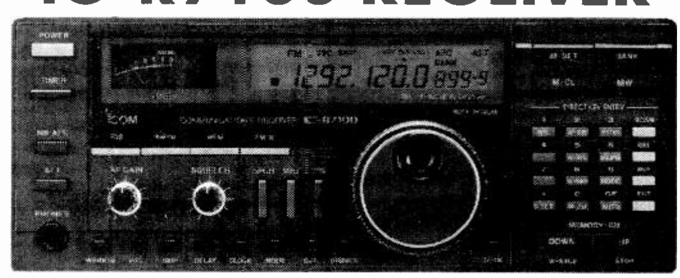

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RESEARCH NOTES

How non-volatile is brainpower?

Education is a vitally important subject: so much so that most of us spend a quarter of our lives consuming it. But does it really matter whether we sharpen our mental skills on Latin verbs or differential calculus, and how much do we retain? To judge from recent research conducted on Open University students, while we may not remember every single fact, we do remember a great deal for a very long time, especially the important general principles – a point companies might ponder before consigning middle-ages wrinklies to the scrap-heap.

Studies of how we remember – or perhaps how we forget – were undertaken on 373 OU graduates, aged between 25 and 72. They were drawn from the 97% of psychology graduates who chose not to work in psychology, and who would therefore have been less likely to top up their mental fact-files. Time from graduation ranged from 3 months to 11 years.

Experiments involved asking questions to reveal deficiencies in different types of memory, for example memory for specific facts, memory for scientific methodology, memory for concepts and principles, etc and tests were designed, as far as possible, to eliminate guesswork.

When all the results were analysed and set against a range of other factors such as the students' ages, grades of degree and levels of interest in the subject, some very interesting conclusions emerged. Results published in *The Psychologist* (Vol 2 No 2 1992) show that even very recent graduates can rarely remember more than about 70% of the factual data they were taught. This, say the researchers, reflects a mixture of knowledge never gained and knowledge quickly lost.

In the case of concepts and general principles, recall is somewhat higher (about 80%) immediately after graduating. Performance is thought to be better because general principles are harder to learn and so are better remembered.

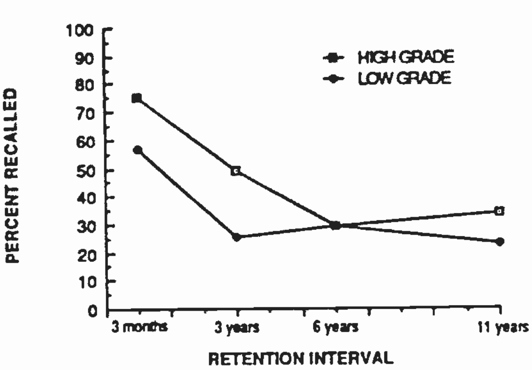
By contrast, individual facts can be learned by rote or swotted up just before an exam, making them more volatile. Exam results, incidentally, are far poorer as predictors of long-term retention than performance on course work – a point for educationalists to note!

What happens in the years after graduating is particularly interesting. Measurements on the OU students show that with virtually all types of memory, the subsequent decline is far from linear. Nearly all the significant memory loss occurs during the first three to six years, after which the curve levels off.

These experimental results obviously have considerable significance when it comes to selection procedures for jobs. Does it, for example, matter what class of degree an applicant gets if memory for what has been learned is more-or-less the same after three years? Is a graduate of three years necessarily a better bet than one of eleven or more?

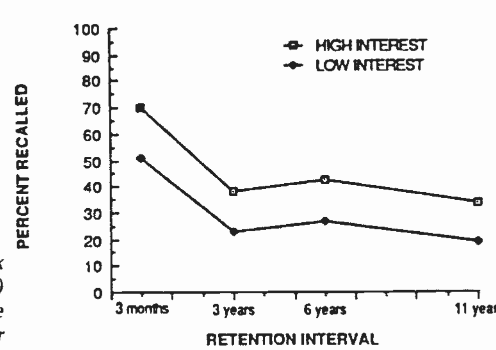
The dreaded subject of ageism is also addressed, very favourably, by this OU study. Although there have been many studies showing that raw IQ declines with age, results of OU degree courses show no age-related performance changes. The researchers conclude that older people, well into their 70s, can often outperform younger students if they are allowed to work at their own pace. The reason seems to be that elderly students are generally more intelligent to start with, as well as being more highly motivated. (There is independent evidence that highly intelligent people retain their intelligence longer. They probably "crystallise" their knowledge and unconsciously develop new mental algorithms to compensate for decreasing processing speed).

The personal characteristics that seem to stand out head-and-shoulders above all other predictive factors for both performance and memory retention over long periods are interest and motivation. So, employers, if you want good long term value from your recruits, ignore degree grades and ignore any sort of examination, especially if conducted within three years of studying. All they may reveal is a candidate's ability to swot. Look instead for evidence of real interest and enthusiasm for the work.



Retention curves (left) for students with good and bad degrees show that both seem to forget at roughly the same rate, though the poorer ones bottom out sooner. Seven years after graduating, there's little to choose between them in terms of their memory for cued recall of concepts.

Students who enjoy their work seem to do better initially (right) and maintain a reasonable memory for it, even 11 years after graduating and possibly for ever.



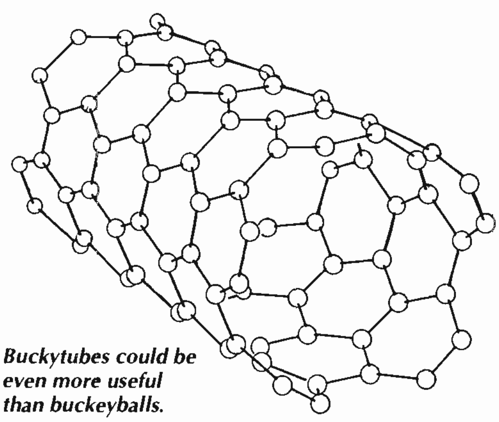
Grow your own micro-wiring

Last November when a Japanese group were investigating the strange football-shaped molecules of carbon now nicknamed "buckyballs", they chanced upon an even stranger form of carbon consisting of microscopic tubes. These "buckytubes" – cylinders of carbon atoms only a few nanometres in diameter are now thought likely to conduct electricity, as well as metals.

Since their discovery in 1985, buckyballs, or fullerenes to give them their formal name, have sparked off a lot of research leading to discoveries of other similar molecules with 76 or more carbon atoms. Chemists and physicists investigating buckyballs soon found, moreover, that it was not just the molecular structure that was different from ordinary forms of carbon such as graphite and diamond. Under certain circumstances, and with the addition of suitable dopants, fullerenes can be made to behave as superconductors and semiconductors.

The recent discovery of "buckytubes" by the Japanese scientist Sumio Lijima of the company NEC was the fortuitous outcome of an attempt to take pictures of buckyballs with an electron microscope. Lijima had been making buckyballs using an electric arc, and was initially disappointed when the high intensity of the electron beam destroyed any trace of them. But as he began to examine the negative electrode of the arc under the electron microscope, Lijima soon discovered something far more interesting: tiny needles of carbon about a micron long and between 4 and 30 nanometres in diameter.

Further investigation revealed that these needles were actually a wholly new form of carbon, consisting of rolled up sheets of atoms arranged in hexagonal patterns, just as they are in graphite. The difference is that with graphite the sheets are flat, whereas the new structures - the buckytubes - are more like hollow, open-ended cylinders.



Buckytubes could be even more useful than buckeyballs.

So far the properties of these new carbon molecules are purely speculative because of the difficulty of conducting laboratory experiments on structures so tiny. But with the dimensions of some of the observed structures in mind, Dr John Mintmire and his colleagues at the Naval Research Laboratory in Washington, DC, have been attempting (*Phys Rev Lett* Vol 68 No5) to predict some of the electrical properties of buckytubes.

Mintmire's calculations suggest that buckytubes will exhibit quantum effects because of the physical dimensions of the structure. His group has calculated, for example, that a buckytube consisting of rings of ten carbon atoms will be an almost perfect conductor of electricity, as good as

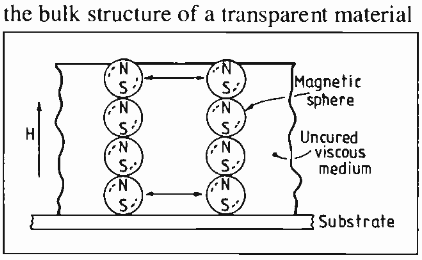
CONTINUED OVER PAGE

Transparently better conductor with write potential

Transparent materials are nearly always electrical insulators because transparency dependends on electrons being relatively immobile. So when transparency and conductivity have to be combined, engineers resort to complicated and often expensive techniques such as ionic liquids or extremely thin metallic films – as in the case of liquid crystal displays.

Coating a metal conductor onto a glass surfaces is certainly useful, but it is not without severe disadvantages. It will not, for example, permit the passage of more than a few milliamps of current, nor will it allow current to flow through the transparent substrate.

But a group from AT&T Bell Laboratories, Murray Hill, NJ and AT&T Technologies in Omaha have now published details (*Science*, Vol 225 p. 446) of a new way of building conductivity into the bulk structure of a transparent material – in this case a special silicone mix. Their ingenious approach involves mixing into the liquid silicone approximately 1% of microscopic nickel spheres coated with gold or silver. The mixture is then placed in a powerful magnetic field which naturally lines up all the spheres in vertical columns.



Structure of the transparent conductor

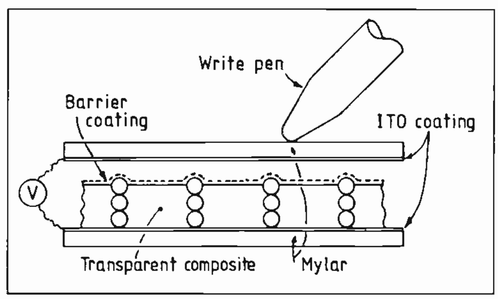
Magnetisation of the individual spheres ensures they are attracted to one another with opposite poles in contact – the same phenomenon that enables a string of ball-bearings to be picked with a bar magnet.

In the case of the nickel micro-spheres the various columns repel one another, leaving regular spaces in between.

The result, once the silicone material has set hard, is a sheet of material containg rows of spheres acting like insulated wires linking opposite faces of the sheet. Because the rows appear end-on to the surface, they intercept virtually no light.

The AT&T researchers say that if the particle content is kept below 0.75%, a 150µm thick layer of the material will transmit about 90% of light falling on its surface – almost as good as a sheet of window glass. Electrical conductivity takes place in the same direction as light transmission, normal to the surface of the sheet.

Such conductivity, through a transparent material, offers enormous scope in imaging and optoelectrical devices.



Using the new medium as write pad

But an even more interesting property has been reported by the group. If a layer of the cured silicone containing the nickel micro-spheres is overlaid with a 5µm barrier layer of plain silicone, conductivity – as expected – becomes negligible. But if the measuring electrode is pressed a little harder, the conductivity suddenly rises.

The researchers say that the underlying mechanism for this reversible switchability is not clearly understood, though what probably happens is that the columns of spheres act like needles and puncture the barrier layer of silicone.

AT&T says that if this sandwich were to be incorporated into a structure with two indium-tin oxide layers and a protective mylar cover it could form the basis of an excellent write-pad device.

the best metals. What is more, unlike many non-metallic conductors such as polyacetylene, the buckytube is expected to possess a zero bandgap at room temperature. A buckytube 1nm in diameter is expected to have a density of charge carriers of between 10^{22} and 10^{23} per cm^3 giving it essentially metallic properties in terms of conductivity. Different sized structures would, needless to say, have different properties

None of these theoretical predictions has yet been tested in practice. Nor has there been any evidence for the existence of buckytubes longer than one micron. Nevertheless the prospects look interesting, especially if they can be synthesised easily and with predictable dimensions. There is obviously the possibility that they could be synthesised like long-chain polymer molecules. They might also be synthesised biologically, in a manner similar to the creation of DNA, the double helix of the genetic code.

Speculative this may be, but success would open up some intriguing possibilities such as the creation of "micro-wire" for connecting up active elements in sub-micron technology. There might also be the possibility of making tiny biologically inert sensors for monitoring what's going on inside individual cells of the body.

Research Notes is written by John Wilson of the BBC World Service.

Brewing quantum chips

Small-particle semiconductor physics is a relatively new field, exploiting quantum effects that occur on the scale of a few nanometres. Particles this small exhibit electronic properties different from either bulk materials or crystalline molecules and in this respect represent a whole new class of materials.

Such quantum semiconductors – they can be created with a wide range of bandgaps – have potential applications in optics, optoelectronics and in chemical catalysis. But there's only one snag: if the material is to have consistent properties, it must be made with particles of precisely uniform size.

Hitherto there have been many attempts to synthesise quantum semiconductor crystallites chemically, usually by restraining the reaction in some way. Not only is it virtually impossible to produce particles of adequate uniformity, it's also difficult to stop subsequent growth by a phenomenon known as Ostwald ripening.

A new way of overcoming these problems and creating precisely uniform crystallites was announced by P Williams and E Keshavarz-Moore (Production of quantum semiconductors by micro-organisms , 1992 IChemE Research Event) involving a process not dissimilar to brewing, using a yeast called Schizosaccharomyces pombe.

If this yeast is grown in the presence of cadmium salts, it reacts – like any living organism – to the toxic effects of cadmium. But instead of curling up and dying, the yeast cells wrap up cadmium particles in a coating of a peptide which isolates the cadmium. Not only does this isolate the cadmium metal, it adds sulphide ions in such a way as to create cadmium sulphide crystallites of almost perfect uniformity. Moreover the size of the crystallites can be "tuned" by controlling the growth conditions of the yeast and are naturally resistant to growth by accretion.

Quantum semiconductors could be useful for a whole range of standard semiconductor applications.

Paul Williams is planning to take advantage of the natural peptide coating to tag the semiconductor particles with molecules that would react with specific biochemicals. In this way it might be possible to create cheap and highly accurate biosensors for use in medicine and in the burgeoning new biotechnology industries.

Sculpted silicon with a humid feel

Sandia National Laboratories of Albuquerque NM has developed a new process for etching silicon to create miniature parts used in micromechanical devices.

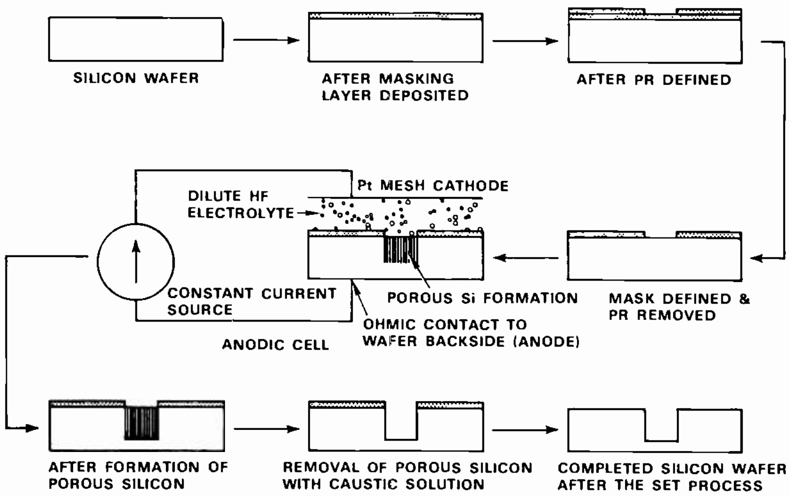
Single crystal silicon has of course long been used to produce integrated circuits. But its exceptional strength also makes it an ideal material for fabricating miniature sensors, motors, accelerometers, and similar devices. The sculpting of these tiny operating structures, measured in microns and often having complex three-dimensional geometries, is still a relatively new field of activity.

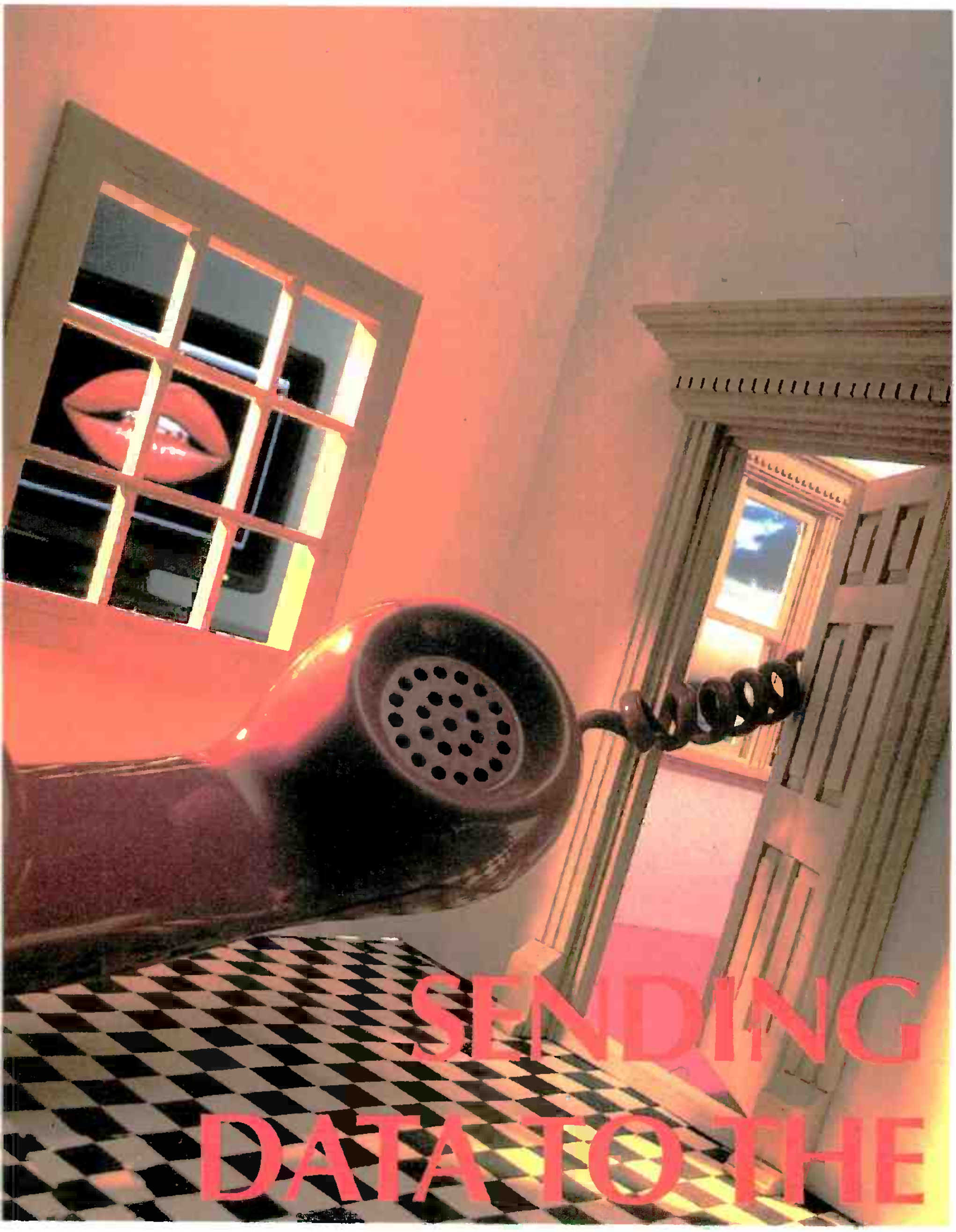
Silicon removal techniques for crafting ordinary silicon wafers involve photolithography and chemical etching. With these techniques, the area to be removed is defined by a patterned mask and the material to be removed is dissolved in hydroxide baths at elevated temperatures. But for three dimensional structures these techniques are less satisfactory. Etch rate is dependent upon the temperature and bath composition, so it is difficult to control precisely the amount of silicon to be removed. Chemical etching also tends to give the etched area a matt finish rather than the preferred mirror finish.

The Sandia process uses electrolysis of silicon in hydrofluoric acid to make porous a very thin layer of silicon on the top of a silicon wafer. Since etching rate is directly proportional to the current passed in the electrochemical cell, the depth of the porous silicon can be easily regulated by controlling the charge passed through the electrochemical cell. The wafer is then removed from the cell, and the porous silicon is etched by immersing it in a hydroxide solution at room temperature. Because the pore depths are so uniform, the resultant etch finish is mirror rather than matt.

A patent application has been filed for a humidity sensor fabricated by the new process, intended to measure humidity inside microelectronic packages and similar environments. ■

Selective electrochemical thining of a silicon wafer





SENDING DATA TO THE OUTER LIMITS

Claud Shannon always knew that the telephone could do more than set up a chat line. Now, fifty years later, modem technology may allow standard analogue speech circuits to reach his predicted limits. By Julia King and Simon Taylor

Four or five years ago, unless an extortionate price was paid, most modems were capable only of data transmission at a rate of 1200 or 2400bits/s. The alternative for users with a need to transmit data at high speed was a leased line.

In the meantime, there have been improvements in terms of modulation technology, the analogue encoding of a digital signal. Borrowing widely from other areas of data transmission and storage, compression algorithms can increase the speed at which data is transmitted; they also bring with them enhanced error correction and detection.

The standard last ratified by the CCITT, V.32bis, is based around a transmission speed of 14,400bits/s full duplex. It incorporates techniques such as auto-adaption (automatic sensing of the line speed being used by a transmitting modem) and retraining (the modem automatically drops down to accommodate reductions in line quality and will train back up again as they improve). The V.32bis renegotiation sequence means that retraining, which used to take around 20 seconds, can now be performed in under one second.

Training is achieved by looking at some parameter, generally residual equaliser error, as a means of establishing line conditions.

Fast retraining is also an important feature for modems used to transmit data over radio. Radio links are half duplex, meaning that training has to be very fast to get decent throughput. The 9600bit/s half duplex V.29 standard needs 270ms to train before any data is sent. This is equivalent to about 40 characters of information at 1200bits/s. The amount of data sent also has to be of reasonable size to benefit from the higher data rate after training, since the larger the packet size, the greater the advantage.

Putting on the squeeze

While modem designers are reaching the limit of higher data speeds, modems have been given a new lease of life with the incorporation of compression techniques. The most successful of these, defined in the CCITT's V.42bis standard, offers an improvement in throughput of between three and four times by using a combination of compression protocols, procedures and algorithms developed by different companies. For instance, V.42bis is based on the data compression model developed by Lempel and Zif, an algorithm widely used for file compression in computing applications.

All of these enhancements mean an increasingly heavy load is being placed on the microprocessor at the heart of the modem. "The processor is running out of steam. People are finding that with the combination of V.32 and V.42bis compression, they're not getting the throughput they should", says Gerry O'Prey, technical director of Dataflex Design. This has resulted in a migration from 8-bit devices generally used for the modem engine to a 16-bit processor.

Hayes' technical director, Bill Pechey, says that the load on the processor will increase still further: "V.fast modems will take about three times as much processing power as V.32 modems". The bulk of the processing is tied up with decoding the encoded modulation, generally using the Viterbi algorithm.

According to Pechey, a recent study of phone lines in Europe and the US has established that performance is better than expected. On the whole, lines have a bandwidth of 3600Hz and a signal to noise ratio of between 30 and 35dB. This means that they are technically able to accommodate transmission rates of 28,800kbit/s – twice the limit laid down in V.32bis.

Although there have been great technical advances in data transmission, the modem remains the domain of the technically aware, to a large extent. The standard way of controlling them remains the AT command set, developed by Hayes, which first appeared some 11 years ago – not the most approachable user interface ever designed.

O'Prey believes that this year will see the emergence of a number of packages designed to ease the user's interface to his modem, just as Windows did for uneasy dos users. A Windows-based interface will hide the vagaries of the AT command set from the user.

Another recent development concerns the ability to incorporate send and receive fax functions. This has been made possible by resolution of the EIA TR29 class 1 and 2 standard, which has provided a common means of sending fax commands from PC-based comms packages to the modem. Until a year ago, the process had to be managed using proprietary packages

Manufacturers are now switching their attention to new issues. As notebook computers increase in popularity, there has been a distinct problem in standardisation of internal card slots. The US PC MCIA (PC memory cards international association) and Japanese Jeida packaging association have now produced a joint standard that accommodates modems and lan and SCSI adapters. The modem will be a credit card sized device; Dataflex has worked closely with Intel and has just launched the UK's first MCIA-conforming modem.

Digital to digital

While modems on analogue lines have reached the data rate limit, ISDN is an entirely different ball park. Obviously no modulation is required because the line is already digital; however, adapters need to perform functions such as taking AT commands and converting them into messages that can be understood by the ISDN line's D-channel.

The limitation with ISDN lies not in the line speed but in the PC's serial port, which is not designed to transfer data at the ISDN rate of 64kbit/s. "Standard comms packages cannot be run at full speed", says O'Prey. This has meant that vendors of ISDN adapters have had to develop their own proprietary APIs (applications program interfaces). Dataflex is overcoming this limitation by launching a package that takes advantage of the comms port's ability to run at 115kbit/s; the signal will then be modulated down to 64kbit/s.

Cellular radio presents modem users with its own problems; of these the greatest is caused by variation in the signal quality and strength, requiring that error correction be truly robust. In the UK, the two cellular operators have chosen different routes for dealing with the problem. Vodafone went the proprietary route, opting to use the BT-developed CDLC protocol, where Cellnet stuck with Microcom's MNP.

Microcom's latest issue, MNP10, a protocol

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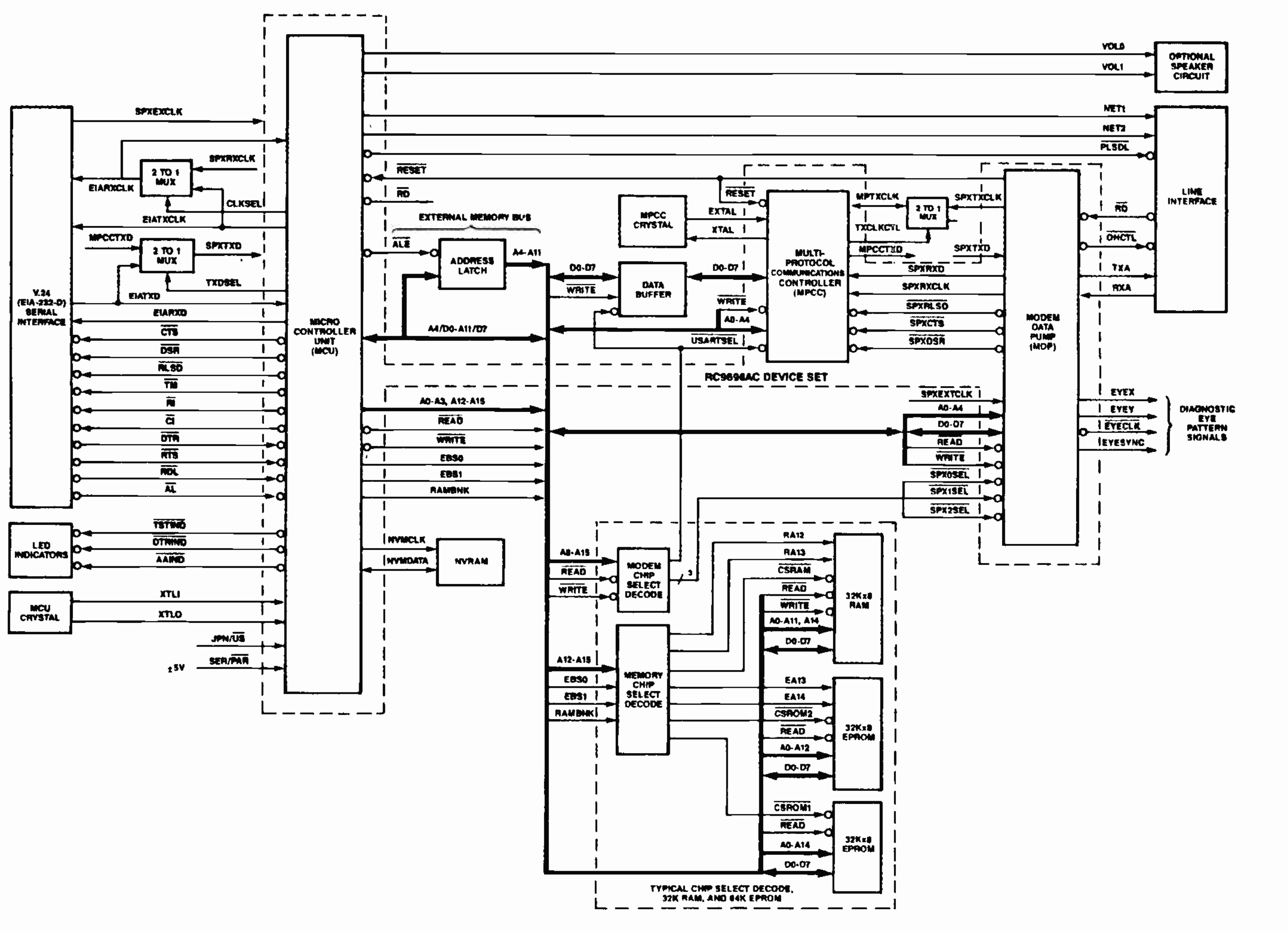


Block diagram of Rockwell International's RC9696AC modem sub-assembly. Providing V32 and lower operating modes together with the on-board error compression and detection of V42, this system makes extensive use of local processing power.

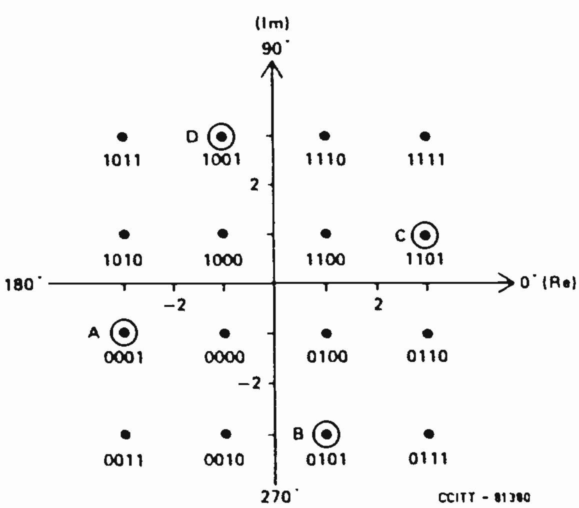
It comprises a microcontroller unit, a communications controller coupled up to a modem data pump, the heart of the system. It uses 32K of ram, 64K of rom and 2K of non-volatile ram.

Useful words to use when talking about modems

Jargon	English
bit/s	bits per second
baud	Period of the encoding frame – the actual data rate may be up to four times the baud rate
Full-duplex (FD)	Transmission in both directions at the same time
Half-duplex (HD)	Transmission in one direction at a time
Pseudo full-duplex	Uses half-duplex transmission, but use of a protocol makes it look like full-duplex
FSK	Frequency shift keying: a frequency defines either a transmitted one or a zero
PSK	Phase shift keying: phase changes define the transmitted bits
QAM	Quadrature amplitude modulation – a derivative of PSK, but also uses amplitude changes.
Leased-line	Usually a 4-wire system that is hired from BT
PSTN	Public switched telephone network (the normal telephone network)
CCITT	An international standards-setting committee. Often other standards appear when the CCITT is slow to react
Hayes	A de-facto standard command set used to control modems (also known as the 'AT' command set)
V.25	An alternative standard defined by the CCITT
V.21	300bit/s FD (FSK)
V.23	1200bit/s one way; 75bit/s the other (slower speeds can also be used) (FSK)
V.22	1200bit/s FD (PSK)
V.22bis	2400bit/s FD (PSK)
V.27	4800bit/s FD on leased-line systems, HD on PSTN
V.29	9600bit/s FD on leased-line systems, HD on PSTN
V.32	9600bit/s FD (PSK)
V.32bis	14400bit/s FD (PSK)
LAP-M	Link Access Procedure for Modem – an error correcting protocol
MNP4	Microcom Networking Protocol level 4, an error-correction system
MNP5	MNP level 5, adds compression at about 2:1, and includes level 4
MNP6	Implements universal link negotiation allowing operation at speeds of 300 to 9600bit/s and statistical duplexing allowing simulation of full duplex service on a half duplex V.29 connection
MNP7	More efficient data compression than class 5
MNP9	Streamlines message acknowledgement and error retransmission
MNP10	Optimises performance with poor line conditions
V.42	The 'alternative' to MNP4, which includes LAP-M and MNP4
V.42bis	The latest ratified system, accepted as a universal standard, which includes MNP5, LAP-M and BTL-Z (British Telecom Lempel-Ziv) algorithm, giving a data compression of 3:1
RS-232	A system for the physical interconnection of equipment
V.24	One of the best known 'standards' commonly known as RS-232; few proper implementations exist
DTE	Data terminal equipment (usually your computer)
DCE	Data connection equipment (usually a peripheral device, modem, printer etc.)

which looks like the X.25 packet handshake, has a high tolerance of poor line conditions. It makes multiple attempts to set up links, it adapts packet size to accommodate varying levels of interference, it negotiates shifts in transmission speed to achieve the maximum acceptable line speed and it shifts dynamically to the modem speed best suited to the line conditions.

Microcom's David Free says that the primary advantage that MNP10 offers over training standards such as V.32bis and V.29 is that it not only trains down as line quality deteriorates but also trains back up again. Data throughput is thus optimised. Microcom also claims that, at signal to noise ratios of 11dB or less, only a class 10 modem is capable of maintaining a communications link.



The baseband signal is modulated in both amplitude and phase; specific combinations correspond to the value – either one or zero – of a particular bit in the bitstream. This diagram represents a signal space map of trellis coded modulation at 9600 bits/s, V.32 standard. Derived from a 1200Hz tone, it sounds like a hiss to the ear.

The binary numbers denote $Y1_n\ Y2_n\ Q3_n\ Q4_n$

The theory

Nyquist, a theoretician stated that the maximum symbol rate (i.e. the baud rate) on a given transmission medium is half the available bandwidth. Telephone lines have a bandwidth of 3000Hz, so this gives a theoretical maximum data rate of 1500bit/s. This is true for FSK modems where different frequencies are used to represent transmitted ones and zeros. But for all other modes, different methods are employed to achieve the higher data rates.

For V.21, the frequencies used are 1180Hz and 980Hz for the transmitting channel, and 1180Hz and 1650Hz for the receiving channel. PSK uses a different method, ie: phase shift keying. This uses a fixed frequency carrier (1200Hz and 2400Hz for V.22bis), and encodes phase changes onto these baseband carriers to transmit the data. If four phase changes are encoded at each sample time, eg: 45°, 135° 225° and 315°, two bits per sample time can be encoded:

45°	00
135°	01
225°	10
315°	11

Sampling at a baud rate of 1200 samples per second with quadrature phase modulation results in a transmission rate of 2400 bits per second. 45° phase changes can be added enabling four bits to be encoded per sample time, giving a transmission rate of 4800 bits per second form the original 1200 baud carrier.

0°	000
45°	001
90°	010
135°	011
180°	100
225°	101
270°	110
315°	111

Noise

Noise is basically interference on the transmitted signal, and comes in different forms: phase jitter, amplitude distortion and noise. All of these can introduce errors into the received data if the noise introduced causes the received point to cross into the zone of another point.

Error correction

Error detection and correction can be used to avoid errors in the signal affecting the received data. Systems such as MNP-4 send data in 'packets' and are acknowledged one at a time as they are sent. Each packet of data has a checksum or CRC which allows the remote modem to detect if any errors have occurred in the transmission process. Error correction may be carried out either by re-transmission of the affected packet, or in some cases by back-tracking of the CRC, enabling the afflicted bit (or bits) to be replaced.

Protocols

To download a file from a bulletin board or some other system, a protocol needs to be used. Protocols are essentially a further 'packetisation' of the data and will operate on top of any existing error correction and compression scheme in use.

In effect this means that two protocols are running at the same time, which is hardly efficient. However, no standards have been set within V.42bis or MNP to enable file transfer to take place; this is still the only way to perform this type of transfer. The modems may have improved but the protocols most people use are still optimised for use with non-error correcting modems. "There are protocols designed for links with error control, such as Y modem G", says Pechey.

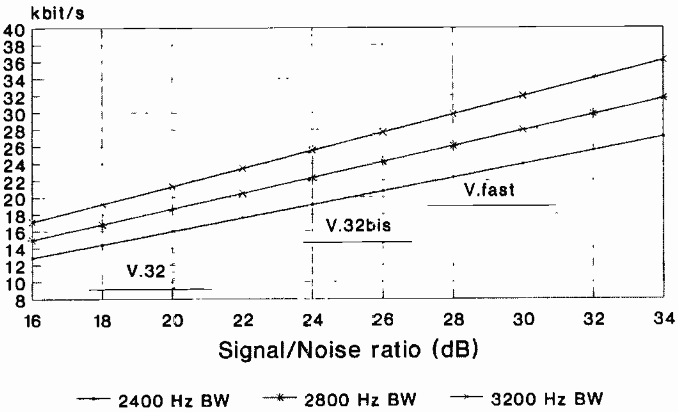
V.fast

The latest proposal, generally known as V.fast and currently under scrutiny by standards authorities, defines a transmission speed of 19,200bit/s. V.fast is thought by most to represent the technical limit for data transmission; indeed, some doubt whether it is achievable. For these reasons, V.fast has already earned itself the nickname of V.last.

Hayes' Bill Pechey, says that V.fast modems will establish initial line speed conditions and so transmission speed by sending a probing signal at the beginning of the handshaking sequence. The modem will then categorise the line into one of several pre-ordained categories before resorting to more traditional training methods.

"The bulk of equalisation will be done in the transmitter", says Pechey. Normally it is done at the receiver. "This will improve the signal to noise performance of the overall system."

Pechey says that if the V.fast modem comes out using the techniques proposed, it will offer performance that falls within 1.5dB of the theoretical limit proposed by Shannon in his capacity theory in the mid-40s. This calculated that the phone line was theoretically capable of accommodating a transmission rate of between 25,000 and 35,000bit/s.



Absolute channel capacity. As channel capacity increases, so does the requirement for improved signal to noise ratio. V.fast requires at least 10dB more headroom to operate than circuits using V.32.

Dialling up a disaster?

Videophones, once great fun in science fiction films, are now accounting for a sizeable slice of electronics company research budgets. In spite of the futuristic appeal, prosaic arguments over technical standards and the eventual price tag make this a high risk strategy.

By Richard Wilson

Recent developments in digital video compression technology and the capability to build reliable flat panel displays may put the first videophones in offices and homes before the end of the year. But we must be careful, much is still fantasy in today's plans for videotelephony.

Companies now believe that they can make videophones with acceptable picture quality at prices a consumer would pay.

Earlier this year AT&T, the US telecommunications giant, demonstrated a videophone which it plans to sell at \$1500 (£800). That product presents grainy colour images on a 9cm screen which scans at between two and 10 frames a second.

British consumer electronics company Amstrad, which ten years ago took the business personal computer into the high street, is competing with BT to put a £500 videophone in the shops before Christmas.

Amstrad's chairman, Alan Sugar maintains that the videophone could become the next great consumer electronics product. He may be right, but it will be another year or more before he finds out whether consumers rush to buy a videophone which will hardly resolve mouth or eye movements. By then more sophisticated videophones with far improved sound and picture quality will be appearing on office desks.

Business videophones currently cost over \$5000 but offer better picture quality; they use larger screens and provide improved definition and motion through the improved bandwidth of digital telephone lines which are becoming available with the introduction of ISDN business services.

Their design is based on an internationally agreed videotelephony standard and, as a result, a large number of manufacturers will be introducing products this year. A dozen or

Europe's first consumer video phones will be in British shops before Christmas according to British Telecom. The instrument is claimed to work on the UK's 22 million analogue telephone lines and will be sold for under £500, or at a discount price of £799 for two so that you can give one to friend.

However, technical doubts remain about both the quality of the picture and, more importantly unless you can lip read, the intelligibility of the audio.

THE NEED TO LIP READ

Poor audio quality is likely to be as much of a problem as poor picture quality as videophone data rates tumble. A digital coding scheme called adaptive pulse code modulation (ADPCM) is used to squeeze a 7kHz audio bandwidth into the 16kbit/s speech channel. This is twice the bandwidth of standard telephones, but still falls well short of the speech quality offered in higher cost video conferencing systems with a 48kbit/s speech channel. Such a system requires a dual ISDN connection or 128kbit/s total channel capacity.

Videophones which work over analogue telephone lines allow only 5.6kbit/s for the speech channel. It is important to remember that these videophones will be telephone handsets with a separate visual image of the caller. It will be some time before products will be able to offer fully integrated sound and vision as we are used to with television and video. In the meanwhile, the expression "watch my lips" could take on a new significance.

more business videophones were to be seen at last year's international telecommunications exhibition in Geneva.

The main issue with videotelephony is how much picture information can be transmitted over the telephone line. Data compression ratios of around 100:1 – that is only one in every hundred bits of picture information is transmitted – are required to squeeze a broadcast quality video picture onto a 128kbit/s telephone connection, allowing at least16kbit/s for the speech channel. This is the equivalent of two 64kbit/s ISDN lines.

Specially designed digital signal processing chips, called video codecs, are used to reduce the amount of data transmitted without cutting picture and audio quality to unacceptable levels. Most systems use an algorithm defined by the international standard known as H.261.

A data reduction ratio greater than 100 to one is achieved by transmitting the information which records when elements, or pixels, of the picture change. In this way the picture is not continually redrawn only modified to accommodate movement.

The H.261 standard defines a number of compression ratios covering a range of picture qualities. A 352 pixel x 288 lines picture format can be transmitted at data rates from 2Mbit/s for high quality down to 64kbit/s which is a signal ISDN telephony channel. The standard specifies a minimum transmission rate of 46.4kbit/s for the video and an audio channel of 16kbit/s.

Videophones benefit from small screens compared to more sophisticated video conferencing systems. Compact systems must use flat panel displays and the current high cost of colour liquid crystal displays is restricting screen sizes to less than 15cm.

According to Martin Redstall, head of BT's videophone group: "A videophone uses a small screen, up to 15cm diagonals, so there is no point in going overboard on the resolution. The important thing is that the angle subtended to the eye should be kept small."

The problem facing companies developing consumer videophones is that scale of compression achieved in H.261 systems is not sufficient to enable acceptable picture quality when transmitted over existing analogue telephone lines. According to BT's Redstall it is possible to compress a videophone picture for transmission over analogue lines at between 8 and 16kbit/s using the H.261 algorithm, but picture quality will be poor.

GEC Marconi is adapting sophisticated data compression and CCD camera technology, originally developed for military hardware, into a videophone which will work over analogue telephone lines. This is the product Amstrad will sell for £500. European telephone companies BT and Deutsche Bundespost Telekom are also said to be interested in it.

Marconi's product compresses both full colour video and telephone quality speech into a 14.4kbit/s data channel using a non-standard algorithm. Cost constraints dictate that it uses a software implementation on standard DSP chips. Marconi has a head start on European rivals and it hopes to create a standard product before the inevitable barrage of consumer products from Japan.

BT along with other European telephone operators are promoting the videophone primarily as a business tool. They believe the use of the H.261 standard and digital telephone lines will ensure acceptable picture quality but it is also seen as a new service which will promote the introduction of ISDN services.

Graham Mills, of BT's videophone marketing group, does not discount the possibility of consumer priced products. "With Japanese companies offering low cost manufacture it could easily become a consumer market."

But the telephone operators are not the only people pinning their hopes on the success of the videophone. PC makers are keen to extend the use of desktop computers outside of the office, and a PC which doubles as a videophone may be the answer.

IBM and Apple are both planning to introduce video compression extension cards and add-on cameras to enable users to turn their

TECHNOLOGY IN THE PICTURE

The CCD imager in the camera unit is a light sensitive two-dimensional array which integrates the optical information falling on it so that an image can be read electrically. The electrical signal is proportional to the incident light on each CCD in the array.

An alternative being developed by Texas Instruments uses a cmos memory array which stores the charge generated by light falling on an array of photosensitive cells.

According to TI the memory array offers improved camera resolution because less optical information is lost compared to CCDs: charge is held in a logic circuit and is read without serial transfer. It also makes it easier to integrate other camera functions such as sweep generators onto a single chip.

An alternative colour camera technology developed by researchers at Edinburgh University uses an array of 84,000 photodiodes and charge sense amplifiers fabricated on the one piece of silicon a few millimetres square.

Flat Panel Displays.
The cost of colour liquid crystal displays has limited videophone screen sizes to 7.5cm. With a price tag of some £100 to £200 per panel there is little incentive to increase screen sizes. Active matrix colour LCD is still far from being a mature technology and manufacturing costs soon become prohibitive. One Japanese supplier says that a 22cm colour display still costs around $1500 to produce.

H.261 Video compression standard.
H.261 specifies the coding and decoding of video signals for video communications services on the public telephone network. It enables video signals to be transmitted over a range of data rates from 56kbit/s up to 1900kbit/s.

The frame structure and synchronisation for video channels from 64kbit/s to 1.92 MBit/s is defined in H.221 and H.230. There is a wideband interface standard for digital channels up to 2MBit/s H.242; and the equivalent narrowband interface H.320.

ISDN Integrated services digital network.
End to end digital telephone connections over the public network. An internationally agreed standard interface consists of two 64kbit/s digital channels which can be used independently or together.

Many of the first digital videophones make use of the combined 128kbit/s ISDN bandwidth which offers best picture and audio quality but at higher service cost. Most manufacturers are now developing 64kbit/s systems.

Video telephony or video conferencing?
Video telephony will offer person to person communications over the public telephone network and so relies on the widest availability of low cost and compatible terminals. Price will be just as important as picture and sound quality.

The video conferencing systems available today are used by companies for group communications with a number of distributed locations. This requires large screens, high video and audio quality and 128kbit/s digital telephone connections.

As a result the cheapest video conferencing systems, at £20,000, are still five times more expensive than the most costly videophones.

EVE-2 European Videophone Experiment.

Public telephone operators in six European countries, including the UK, France and Germany, are attempting to make sure that videophones launched in each country will work together.

The aim to create a standard service based on the H.261 technical interface standard and digital telephone connections. The hope is that it will encourage manufacturers to introduce new low cost products. By the end of the year 50 videophone terminals in six countries will be connected together using public telephone lines.

PCs into videophones. They have enlisted the help of Californian video compression specialists: IBM is working with PictureTel and Apple with Compression Laboratories Incorporated (CLI) which is also working with AT&T on a consumer product. PC videophones and consumer products could offer the right technology and the right product enormous commercial rewards. There is intense pressure to push the technology: video compression, display and camera, as hard as possible.

Designing a custom video codec is expensive, but prices are falling. H.261 codecs which a year ago were restricted to use in $30,000 video conferencing systems could, according to Dataquest, fall to around $7000 by the end of the year.

One result is that a number of US companies continue to develop their own video compression algorithms. They believe the H.261 standard is too restrictive because the best achievable picture quality is sacrificed in favour of low data transmission rates.

Everyone accepts videophone technology must be based on a worldwide standard. "H.261 may not be the best technology but it is the best common technology." says John Tyson, president of CLI.

Improving compression so that video pictures can be transmitted on analogue telephone lines is only the first step. Video telephony must also keep pace with developments in radio communications.

Scientists at BT's research laboratories are already looking at the possibility of handheld videophones which could be used on digital radio communications networks like GSM digital cellular or future personal communications networks (PCNs).

Video telephones may prove to be embarrassing in the home as well as annoying in the office, but inevitably they still carry with them an air of fantasy. The marketing men believe the videophone could have as big an impact on our lives as the TV or PC but then they would say that, wouldn't they?

Richard Wilson is communications editor of Electronics Weekly

KNOWING WHEN TO SAY NODE

The passing of the sullen grey command line interface from the world's desktop computer screens will have a profound effect on both office networking and the companies that supply the software. Dom Pancucci reports

The business of networking personal computers is undergoing a quiet revolution. Where complexity has become the main constraint to the further development of office data communications, suppliers are now seeking ways to simplify the whole process. This will involve downsizing from mainframes to PC networks in the first instance and then making it easy to mix operating systems and applications.

On a hardware level, the role of crucial elements such as hubs will change and inevitably the industry will have to find a common graphical user interface (GUI) to get to the data held across a network. And this will probably signal the emergence of Microsoft's Windows GUI as the front-end most users will encounter on their network in the future.

Downsizing mainframe applications into the PC network is a vital next step required by the network user. Using the client-server model – with a family of PCs served by a more powerful controlling computer – provides a better basis for fast data exchange around an organisation.

Network of operating systems

Compatibility between different operating systems on a network has also become a hot issue. With so many 32-bit operating systems coming out this year – IBM's OS/2 2.0 to Windows New Technology from Microsoft and not forgetting all the different versions of Unix being prepared for the desktop – common threads have to be devised to make them all work together. These will take the form of application programming interfaces (APIs), allowing different software to share data on a network. The APIs will run as sub-sets of operating software held on servers.

The new craze of solving compatibility barriers with APIs has also extended to older technology.

Electronic mail has often been cited as one of three main reasons – along with mainframe connectivity and printer sharing – why networks are installed in the first place. Yet E-mail's acceptance as anything more than a corporate toy has been hindered by the obstinate proprietary tendencies of the suppliers, which have mostly failed to supply mutually compatible E-mail packages.

This problem will soon disappear, because four of the largest Email suppliers – Apple Computer, Lotus Development, Borland International and Novell – have co-developed a standard programming interface called Vendor Independent Messaging. The group of four will soon be expanded when IBM joins later in the year and talks are going on with Microsoft to form a bridge with VIM through its own mail API called MAPI, which will be carried in Windows 3.1. Microsoft claims that MAPI will work with most E-mail products anyway through a server. The problem with E-mail in the past has been the need to initial each address with a distinctive code. Unless your E-mail package knows this initial, it cannot get into the mail box.

Developments such as VIM and MAPI will elevate the role of Email into a key means of accessing corporate data and sending it in a useful form around the organisation. This will be even more important because of the plans afoot to develop integrated relational databases for the now available Windows 3.1 and later versions, which will put all networked information into a central repository and will lead to the concept which Microsoft calls Information At Your Fingertips.

At a more mundane level, the network suppliers are trying to ease bottlenecks in the data traffic by focusing on fewer protocols and miniaturising equipment like network hubs. A report from the 3Com company last year highlighted the cost/complexity problems in expanding existing networks and suggested that simpler cabling arrangements and fewer protocols, among other changes, would go a long way towards easing network growth. 3Com commissioned an independent research firm to do the ground work which went into *The Complexity Crisis* report and the stark message for vendors was to let go of their proprietary technology and adopt an approach based on standards.

Careless talk costs

The cost and inconvenience of making two networked systems talk together when both are based on incompatible architectures or software is simply too great for the enlightened user to tolerate. Although PCs can almost be counted as a standards-based computing environment in their own right – following the continued dominance of the Intel-IBM-Microsoft axis which got the whole thing going in the first place – the servers they are linked to do not always share common technology.

Intel, which identified a PC connectivity crisis itself last summer, has responded to the challenge by developing the Hub Management Interface (HMI) with Novell; the first add-on board product for servers based on this specification is imminent. This will literally bring the hub out of the closet – the central cabling node for a network has up to now been hidden away in a cupboard in a building's basement, or concealed within the risers between floors. In the past a problem with the hub brought the whole network to a halt, possibly for days. Such a catastrophe with HMI-based boards would last only as long as it took to replace the faulty part. HMI products will also raise the throughput of a network, because more of the server's processing power can be harnessed.

Similar board-level products are being rushed out by Intel and IBM, among others, to cope with other aspects of networking and many include built-in management and monitoring software. The aim is to give the user fast access to intelligible information about what is happening on a network. The benefits of HMI's emergence to users is two-fold – support for future hubs based on the specification will be simpler and it could lead to a de facto standard.

"...Windows could be on at least half the desktops in the world by 1995"

Window on the network

Probably the most striking aspect of office datacomms in the near future will be the proliferation of Windows 3.1 as the GUI which is used to navigate networks. Software vendors are vying to develop applications which use Windows better than Microsoft's own products; companies like Novell, which has around 70 per cent of the network operating system business at present, will not want to give up its share. The only way to survive is to develop as many technological plugs into other systems as possible. And Windows could be on at least half the desktops in the world by 1995.

Windows NT itself will be a multi-tasking operating system for the multi-user network. It will come out around the year end. Within that framework Microsoft is planning a suite of connectivity options. Little of this strategy has come out yet in hard specs, but one thing is clear – Information At Your Fingertips will rely on a database which has relational qualities and deals largely in objects. This means being able to match information contained in different computer files and applications and then moving it around in separate chunks which can be manipulated in any way desired.

The issue of databases is one of Microsoft's most closely guarded secrets. Because it has such an importance to the company's future, very few facts have come out about the database project – codename Cirrus – which Microsoft has been working on since at least last year. What has emerged is that Cirrus will work much like a mainframe's database, which is closely linked with the operating system. All applications then write to the database – but with the difference that data stored in separate applications will be accessible by any of the others. The user will retain the benefits of the browsing features of what the industry calls flat file databases if desired.

Microsoft is not alone in seeking this Holy Grail of databases and it will have dramatic effects on networked computing. Borland is also planning a similar suite of integrated databases, running from the desktop to the server, all covered by an object-oriented architecture which will work with Windows. Borland has in fact been beating Microsoft in this game, which has only recently seen the light on object-oriented computing and joined the industry's initiative called the Object Management Group. Other smaller companies will be pitching in as well. And with Windows databases currently claiming only four per cent of the overall database market, it is clear that people are waiting to see what technology will come from the big companies before making a move.

Once the smart databases have become established, the trend towards downsizing will accelerate considerably. By then users will be able to get the storage capacity of the older, big machines with the flexibility of desktop computing. ■

FILLING IN THE WINDOWS

The release of Windows 3.1 marks a turning point in personal computer software technology. Not only will the latest version of Microsoft's graphical user interface become the front end of the company's forthcoming 32-bit operating system called NT, but it will also provide the programmer with an array of tools to tune Windows applications much more sweetly to their real tasks.

Windows 3.1 itself has several improvements over its immediate predecessor. Apart from improved performance, 3.1 includes an advanced scalable fonts technology called TrueType, the file manager has been redesigned and network connectivity has been enhanced. A version of Windows for pen-based and notepad computers has also been announced by Microsoft, which will open the way for better development of the still immature pen computing business.

Microsoft has dominated PC software just like the IBM model has become a standard for hardware. With such a rich release of development tools and operating system potential surrounding Windows 3.1 and NT, the company has set the scene for its continued pre-eminence. Windows is therefore becoming the standard way for the user to get to information held on a PC.

To ease third party product development in the run up to NT's full launch – late this year at the earliest – Microsoft has made available an early application programming interface (API) code for writing to the 32-bit operating system. Called Win32S, it is a sub-set of the full API specification to be included with NT. But it will allow developers to start on applications which will run under the operating system. Older 16-bit software written for the dos operating system will also work with products created using Win32S and the full Win32. Eventually all Windows applications will become 32-bit and future versions of dos will support this migration.

New Windows applications written under Win32 will have distinct advantages over their older 16-bit cousins. They will be capable of preemptive multitasking and will be more closely threaded together.

From the programmer's point of view, toolkits such as Visual•Basic and Object Linking and Embedding (OLE) present some of the more interesting possibilities surrounding Windows 3.1. Both tools, along with Microsoft's C/C++ version seven development system, provide the means of creating object-oriented Windows applications. Upgrades to Visual Basic in particular will see the toolkit shift from its partial involvement with objects to becoming a full-blown object-based system. To that extent it is important that programmers used to procedural software writing methods get to know Visual Basic in its present form – the leap to full object orientation will be mind-blowing for many. The high-performance object technology (HOT) contained in C/C++ version seven will be the basis Microsoft itself will use to develop future Windows systems.

A new version of OLE is also scheduled and its future role in Microsoft development activities remains vague until then. At present OLE is used to transfer objects between applications (hence the linking and embedding), but it could also turn out to the successor to the discrete instructions Microsoft called dynamic data exchange (DDE). Windows applications currently carry DDE messages to allow applications to converse.

In times to come OLE may become the hidden agent allowing the whole object-oriented show to roll on.

SHAREWARE LAYOUT TOOL GIVES INDIVIDUAL PERFORMANCE

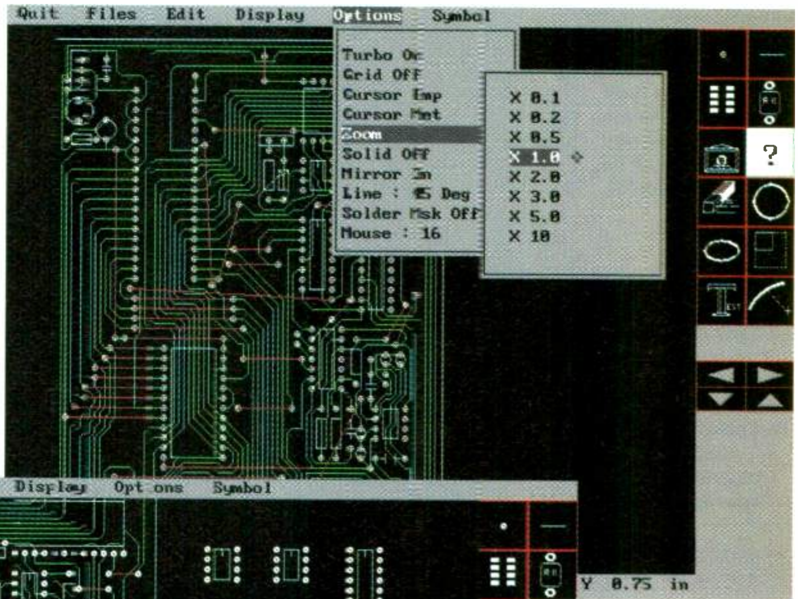
Cheap shareware it may be. But Martin Cummings finds Quickroute's performance puts it in an altogether much bigger league.

Quickroute is a fully functional PCB layout tool that can also be used for drawing schematics. As such it is aimed at a particularly crowded sector of the market, with packages covering most capabilities and budgets. But what immediately sets it apart is that it is on offer as shareware, and at £30 it will undoubtedly interest many designers who have not before had access to such software.

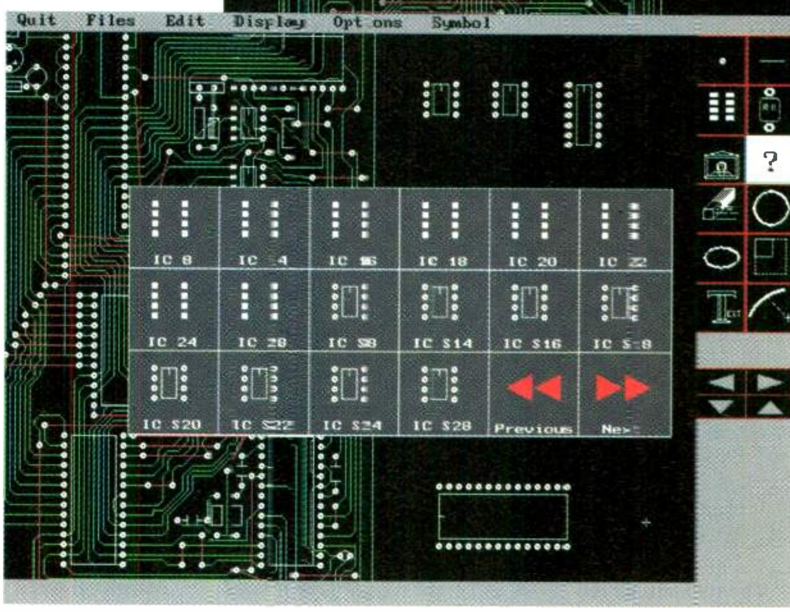
The shareware version starts up with several "marketing screens" showing large text encouraging users to register – it is almost worth paying the £30 to avoid these.

Once through these, the screen layout is a familiar combination of pull-down menus, a bank of point and click icons down the right and a status bar along the bottom.

Cursor keys and function keys can be used to operate the program, but a Microsoft-compatible mouse is supported with the left-button click used to select from the icon bank and the right button pulling down menus. It sounds simple but in practice the arrangement proves surprisingly, and unnecessarily, confusing.



Eight zoom levels can be selected by menu or direct key press.



The range of predefined IC packages proves surprisingly adequate.

Using the package

Probably the most important screen manipulation commands are pan and zoom, and a choice of methods is offered to handle each of them.

Clicking on one of the four arrows on the right pans the screen but a much more attractive method is to press a number from 1 to 8; the screen is redrawn with the current cursor position as centre and with the zoom level being defined by the number. Zoom can also be controlled from a menu and it is not limited to the preset factors, adequate though they are.

Turning on a grid noticeably slows the screen updates, but is difficult to do without, and grid resolution is adjusted automatically according to the zoom level. However the cursor "snap" resolution can be selected from 1in down to just over 0.001in (the manual gives helpful hints about the interaction between cursor steps and screen resolution). Cursor position, in inches or millimetres, is given continuously on the status bar.

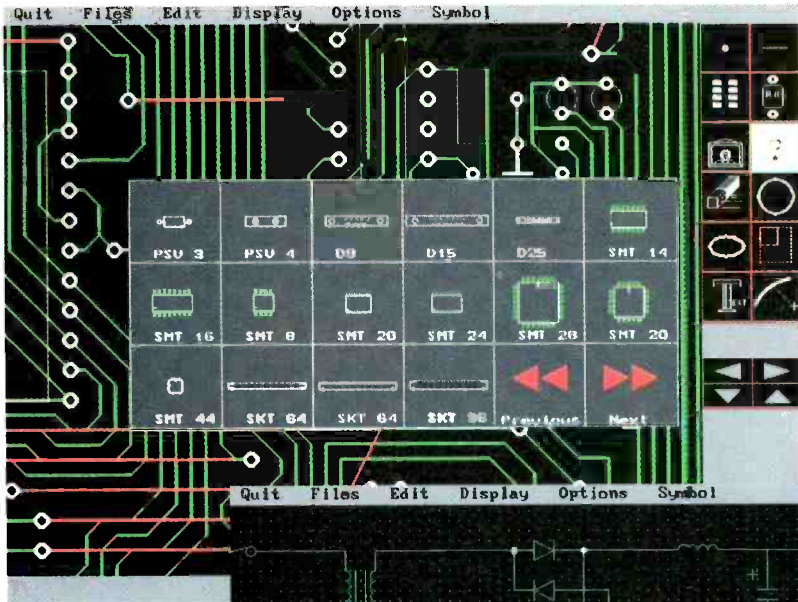
click on the question mark to find out the possibilities.

Powerware would not claim to have provided extensive libraries, but 96 pad types are unlikely to prove limiting and the 16 different IC configurations are surprisingly adequate.

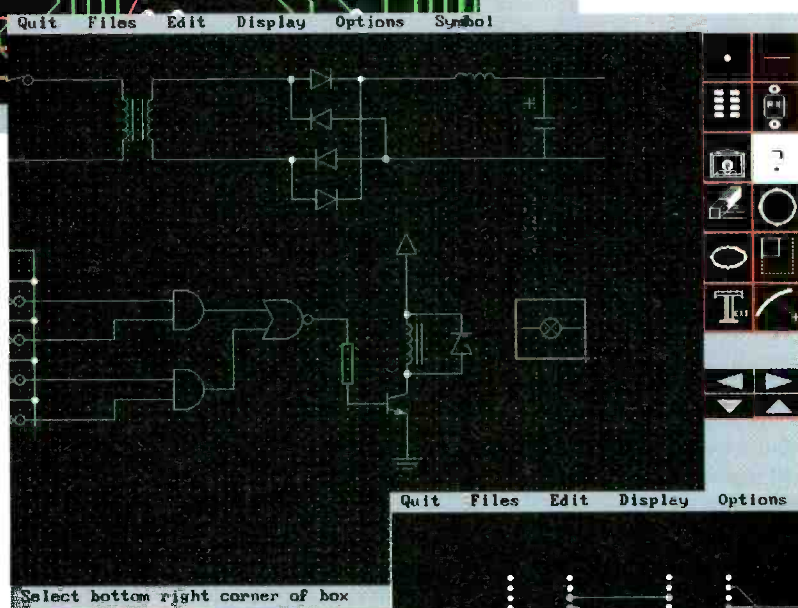
Other components such as passives, D-type connectors, transistors and edge connectors are present. But unless incredibly lucky, most users will soon find it necessary to define their own component layouts. A pleasant surprise is that surface-mount components are included in the library and supported by the package – an impressive addition at this end of the market and not always found in software costing many times more.

Lines, arcs and pads are all available to construct components, and commands and prompts are such that no-one should have difficulty in this area – though the aim appears to have been ease-of-use rather than speed. New libraries can be assembled and though relatively small, limited to 100 components, as many can be used as are needed in a design so the only limit is the space in ram.

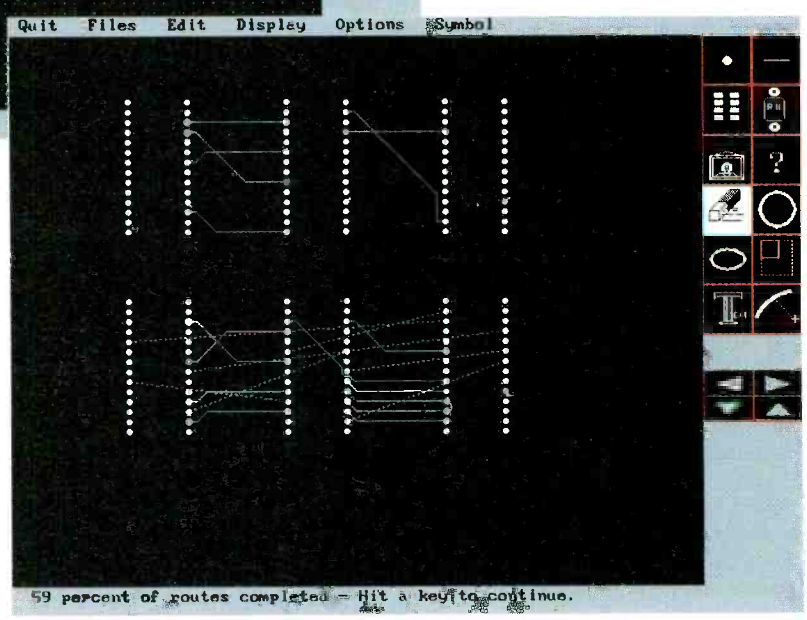
A rough benchmark for memory capacity can be obtained from looking at the layout for a typical microprocessor board with memory and a few discrete components. The completed double-sided, conventional-plated through-hole PCB, about 6 x 4in, takes about 25% of available memory. Maximum permitted board is 37in square. But this would have to be sparsely populated to avoid reaching the memory limit and in any case the sort of board for which the package will be used would be unlikely to approach this.



Surface mount components are included in the library and more can be created.



Component positioning can be a frustrating experience.



Percentage of tracks automatically completed by the autorouter is low.

SYSTEM REQUIREMENTS

Quickroute is a tolerant product and will run on almost any PC-compatible
Floppy disk drive
512K ram
EGA or VGA graphics recommended
CGA or Hercules adaptors enable running in monochrome only.
Software can be run directly from floppy disk but installation is merely a matter of copying all the files onto the hard disk – a utility to install is provided but only works if the source is drive A.
Only 350kbytes of hard disk needed
Executable file needs only 171kbytes.
Mouse
Suitable printer or plott

The two silk screen layers and eight copper layers available may be less than that offered by some other packages but they are more than adequate for most applications. The current working layer is displayed on the status bar and layers can be turned on and off in any combination. Solder resist layers are automatically generated from the pad pattern.

Like most PCB layout software, commands are simple and within minutes you can be placing components on the blank board: first select the object to be placed from the icon bank of tracks, pads, integrated circuits or other components, then

In the registered version, a library of what the manual calls icons (bit images) can be created and built up to include, for example, unusual text characters, arrow heads, target or alignment marks, or any other small but detailed image. The icons are created on a 40 x 40 matrix by deciding which pixels to turn on and off. Unfortunately on CGA or Hercules

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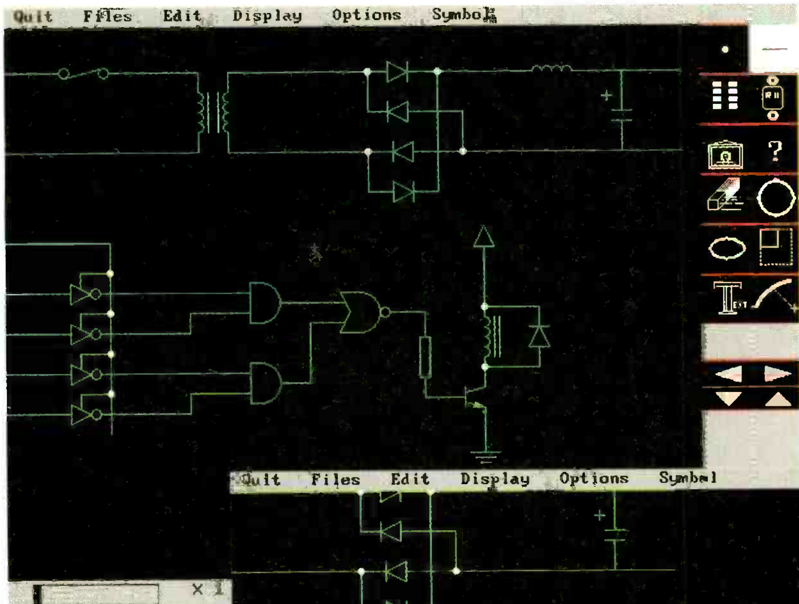
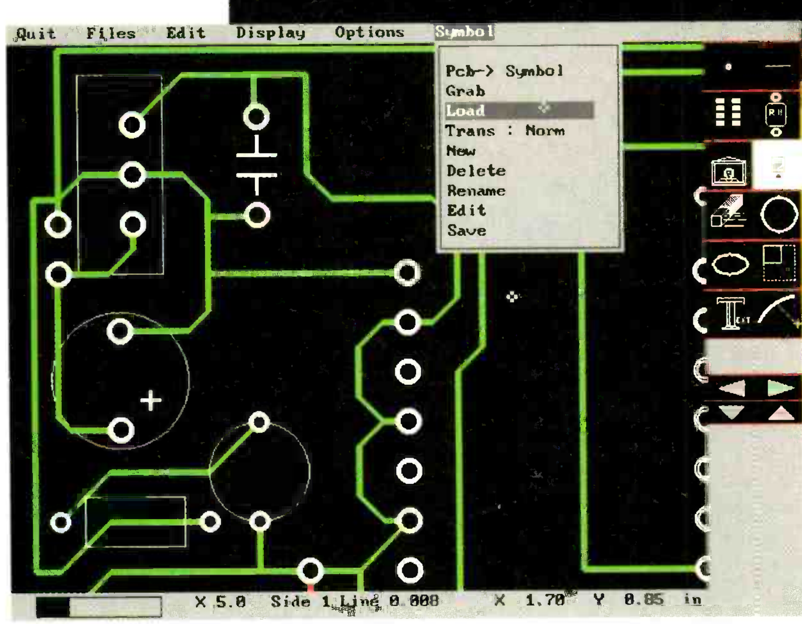


The capability to undertake draughting of schematics doubles the potential of Quickroute.

Circuit schematics can be selected from the menu.



Symbols can be created, edited and saved in libraries.

graphics screen the images can be plotted but not printed, a rather curious and inexplicable limitation.

Positioning problems

Placing components for the first time is straightforward, but trying to adjust their position is certainly bad for the blood pressure. Adjustment sounds easy enough; select BLOCK MOVE then define the opposite corners of a rectangle containing the objects to move. Press ACCEPT and the objects are poised ready to move.

But then comes a subtle problem. The rectangle outline now disappears so although you know where you want to go, it is no longer obvious which part of the rectangle will end up there, making it too easy to slightly misplace the part.

As a result, several attempts may have to be made to locate the object in the right place, causing severe annoyance. Fortunately there is a way around the problem, by always defining the rectangle a known XY distance from the object to be moved. Moving the objects in real time with the mouse, may save many users from an early grave.

By contrast, drawing tracks is easy. Track size can be selected from a choice of 24, or alternative widths typed in, down to a minimum of 0.005in. Tracks can be constructed freely from point to point or constrained to multiples of 45°. As they are drawn, they rubber-band with the cursor, and track width is clearly displayed – a great help when space is tight.

Components initially placed do not come with text such as identifiers, values or part numbers. But any text can be added in a freehand way. Strings of up to 20 characters can be typed in, inverted, reflected or rotated, and placed on the board. Four text sizes are available but only in upper case.

Text is drawn using the current track size; so forget to select a narrow width and your label can look like something written with a badly worn felt tip marker.

Once a design has been created it will usually need editing, by deleting, moving and adding a few parts here and there. The delete command works well if you know exactly where to click on the offending item, though it is usually much easier to delete a block by defining a rectangle then obliterating it. Areas of the design that may be of use on other layouts can be extracted and saved to file using the GRAB command.

Autorouting capability

Almost unbelievably, at this price, Quickroute comes with an autorouter. To make use of it, first tell the program which two points to connect by clicking with the mouse on the appropriate pads. As each point-to-point connection is entered, a straight line linking them is drawn so building up a rat's nest on the screen. Up to 99 links can be entered at a time although some users may wish to enter and route on a one-by-one basis. Pressing the left mouse-button defines the links. Unfortunately in the middle of the process it is all to easy to press the right mouse button by mistake, terminating the defining mode and prematurely unleashing the autorouter.

The autorouter defaults to a track width of 0.0125in which is also the largest width it can deal with. But width can be modified down to 0.005in if needed. Quickroute's algorithm attempts to route within a rectangle defined by the connection points, and on any of the layers that are selected to be displayed. Layers are tried one by one, but a via-hole is not used to move layers within a route.

I put the autorouter though its paces with a simple test to route ten tracks on a fairly spacious array of ICs with no

CONTINUED OVER PAGE

SHAREWARE

Shareware can be copied and distributed at will, so that potential users have the chance to try software before purchase. Those that continue to use it are required to pay the fee to the author and in return get documentation and an up-to-date version of the package.

In the shareware version of Quickroute, all you get is a disk and a text file giving brief instructions, sufficient for most people to explore Quickroute.

Registration brings a manual – over 40 pages of A4 – providing more detailed instructions. The registered software also comes with additional output drivers to support HPGL plotters and Laserjet printers, but is otherwise identical to the shareware version.

Quickroute's manual gallops through the features, explaining exactly what to do, how to get the best from the program and any limitations to be kept in mind. It is a little short on diagrams and would benefit from an index and contents page. However Quickroute is easy to pick up and explore so the manual is only occasionally used.

other existing tracks to get in the way. It managed to complete a rather disappointing four routes successfully, but must be given credit for being optimistic because it reported "45% of routes completed".

A designer would try to keep tracks predominantly horizontal on one layer and vertical on another. The QR autorouter does not apply this strategy so would be more trouble than it is worth on reasonably dense digital boards, though may have appeal in less critical applications.

Hard copy

Eventually all layouts need a hard copy, either for checking or as final artwork. The shareware version comes with drivers for Epson or IBM-compatible nine-pin printers. After registration the full version comes with drivers for 24-pin Epson-compatibles, HPGL plotters and Laserjet printers.

Layers selected to be displayed on the screen determine those that will appear on the hard copy so layers can be printed separately or in any combination. The screen zoom factor also influences size of output.

Where artwork turns out to be larger than the printer or plotter, it can be created in several strips to be married together later by hand.

Even cheap and cheerful dot matrix printers have a resolution of around 240dots/in – nigh on 4thou – and while this may not be adequate for designing, say, 80486 motherboards, for most people it will be adequate. Laser printers and plotters will do better.

Overall scaling can be adjusted using the zoom factor, and it is also possible to make fine tuning adjustments to the Y-axis scaling – useful for compensating for printer wear, paper stretch or slip around rollers. The plotter driver allows adjustment of pen width and velocity.

Once all the menu selections have been made and a printout requested the screen goes blank so that while the printer is in action, all that is shown is a small flashing cursor. The rather unfortunate impression is that the system is having to think hard to carry out printing. But the results are excellent, even on a nine-pin dot matrix printer, and a most professional result can be obtained with a laser. Quality of the finished artwork depends not on the program, but on the output device used and the medium on which it is printed.

SUPPLIER DETAILS

Write to Powerware, 14 Ley Lane, Marple Bridge, Stockport SK6 5DD, or available through shareware catalogues. Shareware version £5, registered version £30 (includes manual 24 pin Epson driver, Laserjet driver, plotter driver and icon editor).

Drawing schematics

The manual introduces the possibility of using Quickroute for drawing schematics as well as PCB layout almost as an afterthought. But the capability almost doubles the potential uses of the package.

All that is necessary is to load in a library of circuit symbols which can be placed and connected in the same way as their physical counterparts. A library of symbols included has 41 different circuit elements from switches and fuses through to transistors and gates.

Inevitably more circuit symbols will need to be created but this can easily be done by either constructing from primitives or in most cases by using the bit image editor provided with the full version. Unfortunately the problem that makes component-moving such an imprecise art is even more evident when draughting schematics. For example, it is quite usual to want to place a transistor such that its base connects to an existing resistor. Use of a grid gives a fighting chance, but a more user-friendly MOVE command is high on my wish list.

Big league performance

Shareware is generally the bargain basement of the software market, but such generalisations are always dangerous. Quickroute started life as a standard commercial product and was recently brought into the shareware market to broaden its availability and no doubt increase cash flow to the author.

Because of this, it has many more features than its price and place in the market might suggest.

Those with an occasional need for high-quality artwork who perhaps previously could not justify the investment will now find that the cost of the software is insignificant compared with that of the hardware to support it.

In higher education Quickroute could be used not only to generate artwork but also to introduce students to cad techniques. Even schools that have Acorn computers such as the A3000 or A5000 and a PC emulator should be able to run the package and its price makes it similar in cost to a lot of educational software.

The autorouter may only be a token gesture but if it can illustrate the principle it may sow the seeds of a future career for students exposed to it. There is also the hope expressed in the manual that if sufficientpeople register, the program can be enhanced to provide a more elaborate autorouter, bills of materials, net-lists and that important step in automation – linking schematic capture to the layout process.

In-depth professional users will inevitably come up against the package's limitations in performance, but this is not the market in which Quickroute is expected to flourish. In fact it is tempting though wrong to compare it with software on the market for hundreds or even thousands of pounds.

So, though many will find that the user interface could be improved, there are plenty of features to compensate. If you are prepared to persevere, almost any feature can be put on artwork, one way or another. Finally, Quickroute can be a no risk investment because as shareware you can sample it before you buy. ■

BRIEF SPECIFICATIONS

Eight copper layers
Two silk screens
Solder resist generation
PCBs up to 37in square
Min track width 5thou
Simple autorouter
Flexible zoom and pan
Component libraries

PLUGGING-IN TO DSP POWER

Stand-alone real-time data acquisition or very fast processing, Allen Brown plugs in two cards that really pack the punch of the DSP96002.

The DSP96002, furnished with floating point capabilities to the IEEE-754 standard, represents one of the most powerful floating point digital signal processors (FP-DSPs) currently on the market. Motorola launched the FP-DSP in 1990, and its ten 96-bit general purpose registers (accumulators) indicate the level of complexity. Now the processor has been incorporated on a number of expansion cards for both VME and PC systems. Two of them are the DSP96002 system board from Loughborough Sound Images and the MM-96 from Ariel of New Jersey (distributed in the UK by Dataß).

Direct comparison of the Loughborough Sound Images (LSI) product and the MM-96 is inappropriate since their individual functions are somewhat different. The LSI board is designed as a stand-alone real-time data acquisition and processing card while the MM-96 is very much a processing card, carrying two DSP96002s – though auxiliary cards are available for providing data acquisition on the MM-96.

Real time data acquisition

LSI, one of the market leaders in the manufacture of expansion cards hosting DSP chips, released its system card featuring the Motorola DSP96002 processor in 1991.

In a slight departure from its conventional design, LSI has incorporated a motorway parallel expansion connector which allows daughter boards hosting other DSP96002 processors to be configured into a multiprocessor system.

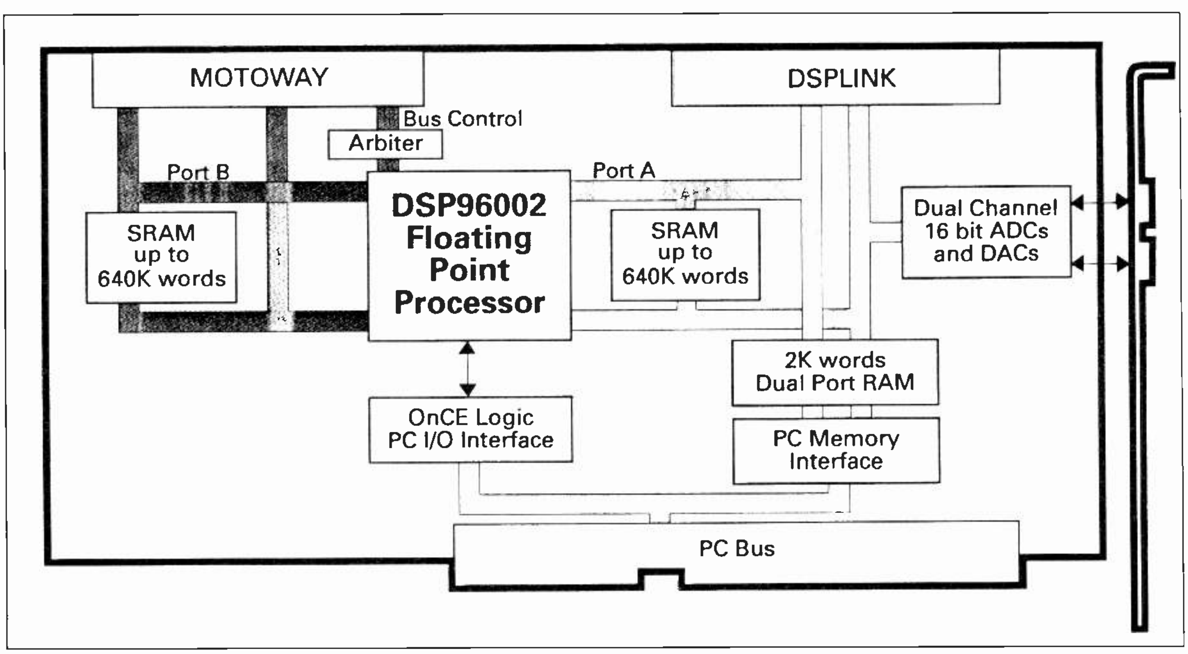
In the LSI system board the DSP96002's own memory is augmented with board static ram (sram) which can be equally divided between the two expansion ports on the processor.

Standard memory is 320k x 32-bit words – expandable to 5Mbyte – and one of the clever design features is the option of mapping its P, X or Y memory between the expansion ports A and B.

LSI allows the sram to be allocated in one of two ways: the first is the non-overlay mode where half the sram is given over to P memory and the other half divided between Y and X memory. External memory is contiguous with the on-board memory of the processor (P Y and X).

In overlay mode all the external memory is assigned to one bus and is contiguous with the respective memory on the processor. Selection is performed through the operating mode

In the LSI system board the DSP96002's own memory is augmented with board sram which can be equally divided between the two expansion ports on the processor.



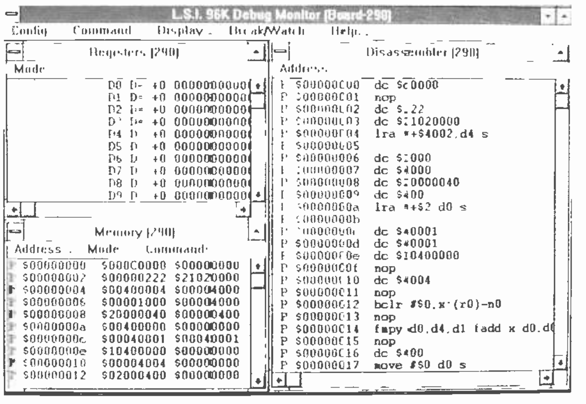
register (OMR) and the port select register (PSR). Sram can be augmented to a maximum of 5Mbyte and for cost consideration purposes wait states can be included in the DSP96002 memory access timing.

8k-words of dual-port memory (dpram) ease communication between host PC and the DSP96002 expansion card, and in effect this is used as a data dumping cache to enable two-way communication without compromising operational performance. The dpram is in fact memory mapped into the PC memory map and is used in conjunction with the processor's DMA controller to effect data transfer.

As with the other expansion boards the DSP96002 system board comes complete with two analogue channels (two separate A-to-Ds and two separate D-to-As). The A-to-Ds are in fact Motorola's own 16-bit DSP56ADC16s and are based on Sigma-Delta technology. Maximum sampling rate is 400kHz (for 12-bits), though this can be reduced through software down to 32kHz.

For 16-bit conversions, the maximum conversion rate is 100kHz and minimum 8kHz. The D-to-As are Burr Brown's PCM56 16-bit devices and are matched with two fourth-order Butterworth filters which act as reconstruction filters. The D-to-As and the A-to-Ds are interfaced to the DSP96002 via an asic which enables them to be memory mapped into the two separate address spaces (X and Y). This allows simultaneous operation of the two analogue channels (A and B).

The asic is also responsible for clocking the analogue devices and setting the clocking period for them.



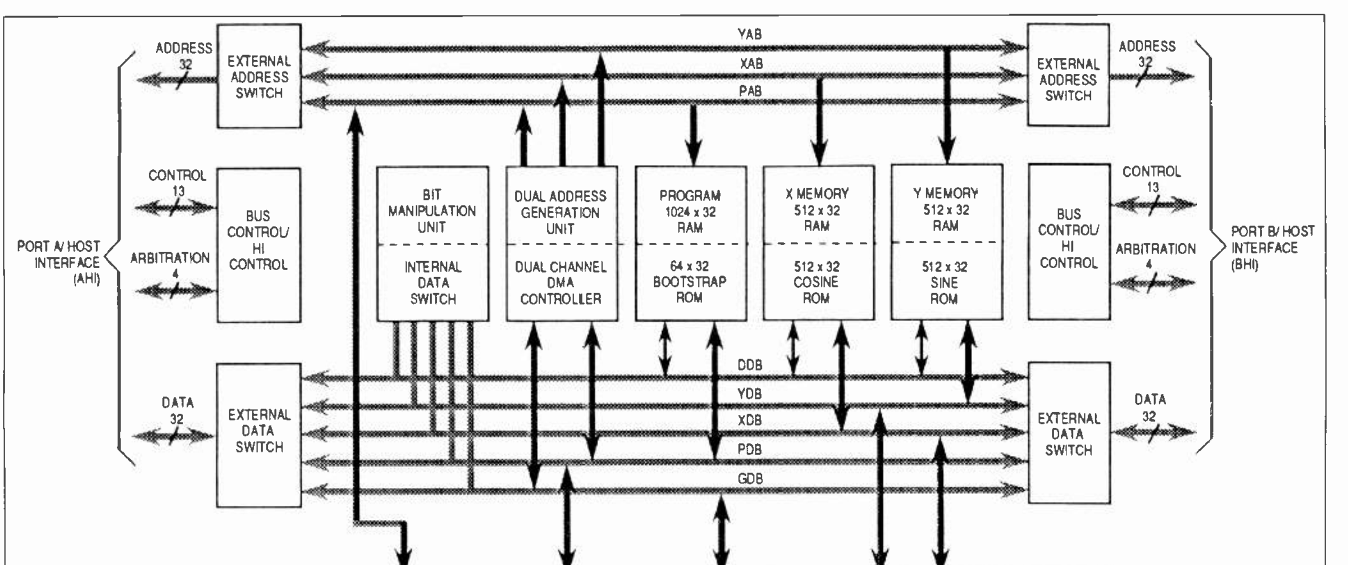
View96 partitions each window into several sub-windows.

Software support tools

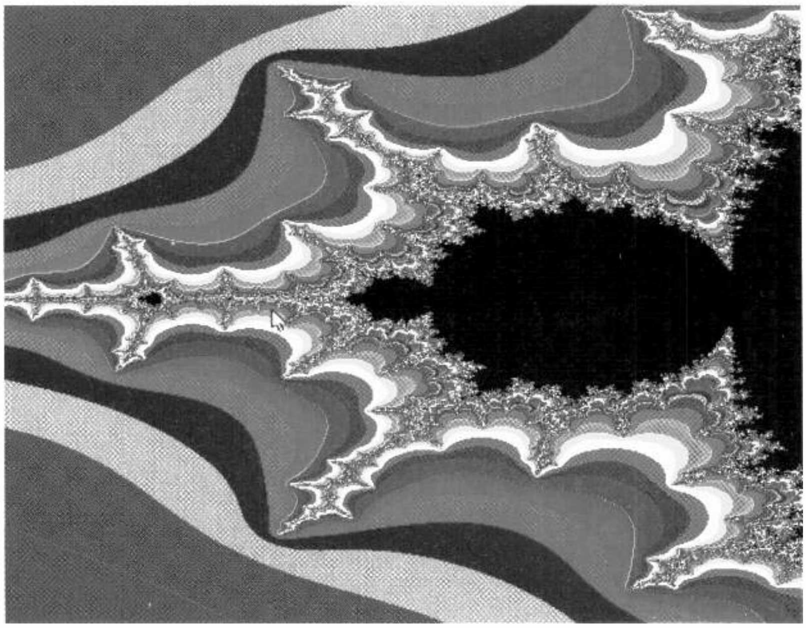
On-chip emulation (once), in itself an innovation, is used to great effect to implement debugging operations. One of the principal software support tools provided by LSI is the Mon96 monitor which uses part of the dpram to allow the processor to operate unhindered. All the usual features expected of a processor monitor are here – for example single step, break points, memory and register display – and the extensive range of commands can be viewed by evoking the help instruction. Unfortunately though the monitor is a useful debugging aid it lacks the normal screen refresh display

DSP96002 architecture

In the DSP96002, the various functional elements are serviced by a wealth of internal buses. Dual nature is key to the chip's design philosophy and encompasses data memory spaces, the address arithmetic units and an on-board dual channel direct memory access controller. The two ram areas (X and Y) can be accessed concurrently. An abundance of internal 32-bit data buses allows a high degree of parallelism: for data transfer purposes, there are two local bidirectional data buses (YDB) and (XDB), program data bus (PDB), global data bus (GDB) and the DMA data bus (DDB). These buses support the normal register-to-register and register to



A wealth of internal buses serve the DSP96002.



Fractal plot completed in less than 7s on the MM-96 board.

facilities expected these days. But LSI has now introduced a Windows compatible debugging facility, View96, employing the Microsoft graphics user interface (GUI). When a 386 PC is operated with several 96002 system boards for multiprocessing purposes, a View96 window can be dedicated to each board. Hence each processor can be monitored during program execution.

View96 partitions each window in several sub-windows. Each sub-window can display a particular aspect of the DSP96002, for example the disassembly of code or the contents of a data memory. The contents of the sub-windows are refreshed after a monitor event has caused data values to have changed. Once View96 has been evoked, the full range of facilities become available from the drop-down menus. View96 offers many of the features of Mon96 except that access and display is a little more modern.

Exceptional number cruncher

Ariel Corporation (represented in the UK by Dataß) supplies an expansion card for the PC with two DSP96002 floating point processors; computational power of the board is quite exceptional. For example only 7s is needed to perform a Mardelbrot fractal plot consisting of 640 x 480 pixels. The MM-96 is rated as a 100Mflops (IEEE-754 single extended precision) system when the dual processors are used in parallel (clock speed of 33MHz). Its three banks of zero wait-state memory can be increased to 16Mwords.

To ensure rapid data throughput the board has DT-Connect the standard video/graphics interface, DSPnet the multi-master parallel interface and dual expansion ports for interconnecting multiple boards on the HyperBus standard.

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memory dual 32-bit transfer or can be combined to transfer a 64-bit word (the GDB is employed in i/o operations).

For address purposes, there are three internal address buses; for the Y ram (YAB), the X ram (XAB) and for the program ram P (PAB). The 32-bit buses may gain access to the outside via the external address multiplexer.

Memory spaces

The DSP96002's three separate memory spaces, X data memory, Y data memory and program data memory each has a range of 4Giga locations. Most of the memory area is located externally and is addressed, via a multiplexer, by the three 32-bit address buses (YAB, XAB and PAB).

Allocation of program memory area is determined by the MA, MB and MC bits (**Fig. 2**) found in the operating mode register (OMR).

The 32-bit X data memory can be configured in one of two ways depending of the setting of the DE bit in the OMR. When DE=1, the on-board ram occupies 512 locations with the address range 0-1FF (hex). On-board rom occupies 1024 locations, given over to a cosine coefficient table. The remaining address locations are taken up with external X-data memory, apart from 128 addresses at the end of the address range dedicated to the various on-board peripherals.

When DE=0, the internal X-rom is not available and the remaining address range is given over to the external X-data area. Y-data memory is configured in the same way as the X-data memory when DE=1 except the 128 locations at the end of the address range are dedicated to external peripherals. Address range 400-7FF hex is taken up with a sine coefficient table.

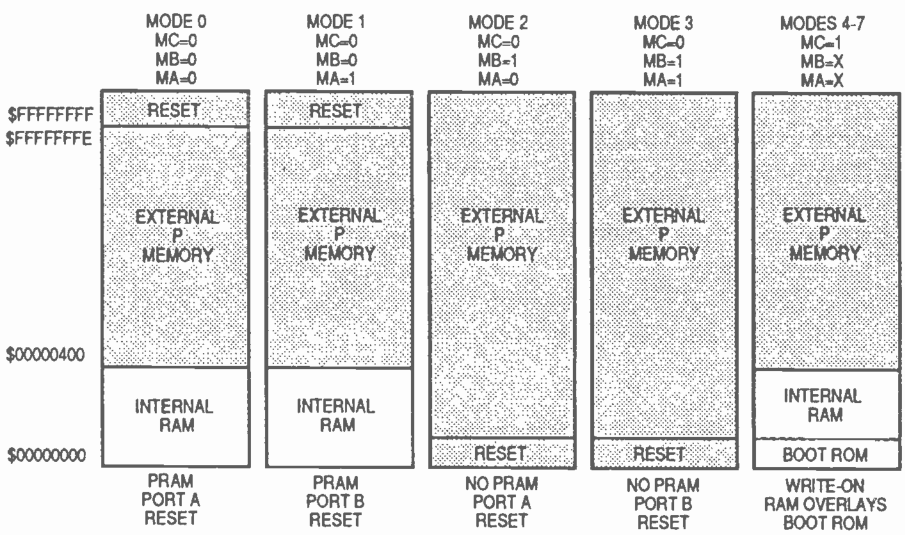
External peripherals can be accessed by using the assembly language instruction MOVEP for byte transfer. When DE=0 the on-board Y-data rom is not available and that space is taken up by the external Y-data memory.

Program memory (pram) consists of 1024 locations of internal 32-bit ram with the remaining address range external to the processor. Pram can be configured in one of eight ways depending on the mode setting. The M flags in the OMR (MC, MB and MA) allow eight modes to be realised. The first 512 pram locations are taken up with interrupt vectors leaving the other 512 locations available for cache memory. This is possible since the code in the pram may be changed under program control using the DMA – a type of overlay mechanism. Boot rom can be loaded from slow external memory.

In addition, a system stack (a separate on-board ram area, 64-bits wide with a depth of 15, operating first-in/last-out) acts like a normal microprocessor to effect context switching. It is also used to achieve zero overhead looping (DO instructions) and for this purpose has the following features:

- For nesting loops, the current loop counter and loop address register can be stored on the stack;
- The loop counter and loop address register

Allocation of program memory area is determined by the MA, MB and MC bits.



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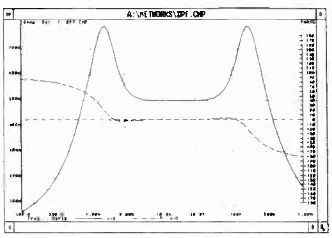
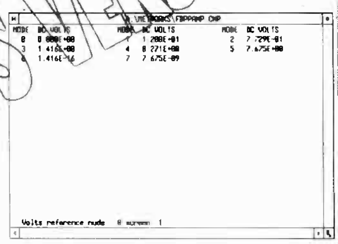


Impedance sweep

1 Frequency response
SPICE●AGE provides a clever hidden benefit. It first solves for circuit quiescence and only when the operating point is established does it release the correct small-signal results. This essential concept is featured in all Those Engineers' software. Numerical and graphical (log & lin) impedance, gain and phase results can be generated. A 'probe node' feature allows the output nodes to be changed. Output may be either dB or volts: the zero dB reference can be defined in six different ways.

2 DC Quiescent analysis
SPICE●AGE analyses DC voltages in any network and is useful, for example, for setting transistor bias. Non-linear components such as transistors and diodes are catered for. (The disk library of network models contains many commonly-used components – see below). This type of analysis is ideal for confirming bias conditions and establishing clipping margin prior to performing a transient analysis. Tabular results are given for each node; the reference node is user-selectable.



DC conditions within amplifier circuit

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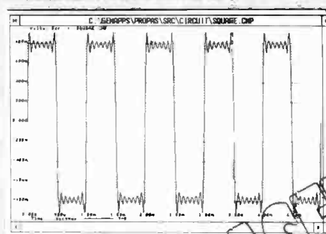
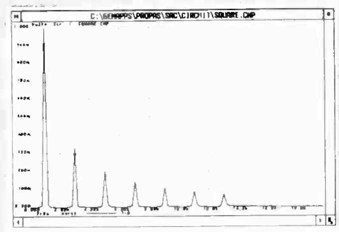


Square wave synthesis (transient analysis)

3 Transient analysis
The transient response arising from a wide range of inputs can be examined. 7 types of excitation are offered (impulse, sine wave, step, triangle, ramp, square, and pulse train); the parameters of each are user-definable. Reactive components may be pre-charged to steady-state condition. Up to 13 voltage generators and current generators may be connected. Sweep time is adjustable. Up to 4 probe nodes are allowed, and simultaneous plots permit easy comparison of results.

4 Fourier analyses now with Hanning window option
SPICE●AGE performs Fourier transforms on transient analysis data. This allows users to examine transient analysis waveforms for the most prevalent frequency components (amplitude is plotted against frequency). Functions as a simple spectrum analyser for snapshots of transients. Automatically interpolates from transient analysis data and handles up to 512 data values. Allows examination of waveform through different windows. Powerful analytical function is extremely easy to use.



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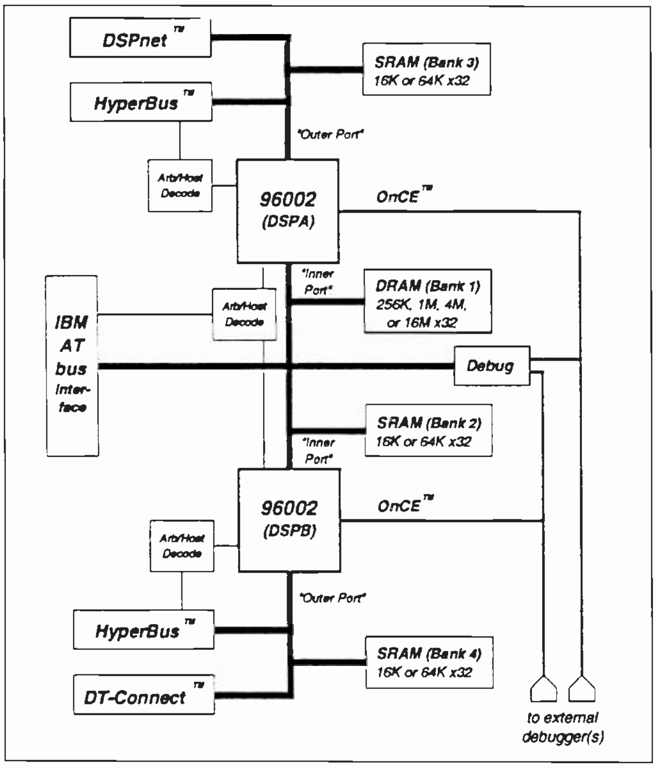


The board has three banks of zero wait-state sram (banks 2, 3 and 4) and one bank of dynamic ram (dram)..Processors have exclusive use of one bank each (bank-3 for DSPA and bank-4 for DSPB) and access is through the respective processor's outer port. Each outer port is also linked to the processor's respective HyperBus port.

The third bank of sram is shared by the two processors and is accessed through the inner port. Inner ports of both processors are also connected to the IBM industry standard interface (ISA – the PC bus).

Standard allocation of memory to each sram bank is 16kwords but this can be upgraded to 64kwords. The MM-96 also has a fast page-mode dynamic ram area (bank-1) with a standard size of 256kwords, but this can be upgraded to 16Mwords.

Page-mode access is the fastest use of dram due to the dual row and column addressing needed. The MM-96 is designed with the dram contiguous with the DSP96002's own memory and the appropriate signals are generated to enable fast page sram read/write. By this means only one wait state need be inserted for a read, and two wait states for a write for 60ns access time dram.

Normal random access would require six wait states.

Signal processing

For performing signal processing tasks the MM-96 makes very effective use of the DSP96002's port select register (PSR) which determines theusage of its ports.

Dynamic allocation of memory is an important requirement when performing differing types of operations. Three distinct needs have been identified and the memory can be configured accordingly: scalar processing – simultaneous access of program memory and data memory (Harvard memory design; vectorial data processing – the data memory is partitioned into X and Y which can be accessed simultaneously; and double precision floating point recursive arithmetic – the memory can be used to store 64-bit floating point numbers.

In design of complex microprocessors, manufacturers have recognised the difficulties in emending software errors. Motorola addressed this problem with its on chip emulation facility and full access to this is included in the MM-96, achieved through once ports A and B, connected to two D-type connectors (one for each processor) on the back-face of the expansion card.

Inadequate user manual

Software supplied with the MM-96 provides a number of interesting facilities and demo programs.

are initialised for the new loop.
•The address of the first instruction in the program loop and the current status register are transferred onto the system stack.
•The loop flag in the status register is set.
When the new loop is expired, the virtual state of the previous loop is restored from the system stack and continues as normal. As expected, there is a limit on the number of loops which can be nested depending on how much information is stored on each loop call.

Data arithmetic logic unit

The data ALU (**Fig. 3**) is responsible for performing mathematical operations in several formats ranging from fixed point to floating point manipulation with various rounding modes. The data ALU has the following features;
•A file with ten 96-bit general purpose registers
•32-bit barrel shifter
•32 x 32-bit parallel multiplier
•32-bit adder
•Format converter
•Divide and square root unit
•Controller and arbitrator
The ten 96-bit registers in the data ALU (D0-D9) are serviced by the XDB and the YDB, both providing either 32-bit or 64-bit operands. In fact the register file acts like ten separate accumulators with the restriction that D8 and D9 are not used as destination for data ALU operations.

With 96-bits registers, data can be stored as double precision floating point numbers and as numbers are loaded into the registers, a format converter can act to change the representation to a desired format (IEEE-754 for example).

Strength of the data ALU is its ability to perform complete mathematical operations in a single machine cycle – a standard feature for DSPs. For example in 60ns it can perform a 32 x 32-bit floating point multiplication, floating point addition and format conversion.

Floating point operations always give risê to 96-bit results whereas fixed point operations will give either 32-bit or 64-bit results.

Floating point operation conforms to the IEEE-754 standard for 44-bit single extended precision. The four IEE-754 rounding modes are implemented (round to zero, round to the nearest, round to plus infinity and round to minus infinity). The flush-to-zero mode is also supported, causing an underflow calculation to generate a zero.

C COMPILERS

One of the C compilers for the DSP96002 is produced by a third party company, Intermetrics Microsystems Software. The C compiler is part of the InterTools package consisting of an integrated suit of software development tools for the DSP96002. It includes a compiler, an optimser, a run time library, an assembler, a linker, a formatter, a librarian, a symbol utility and a source level debugger.

The InterTools package is available for all commercial computer systems and for the PC it comes on six high density discs.

The large number of switches makes it look as though almost every option has been covered.

Communication between the PC host and the MM-96 is quite a complex affair involving numerous interrupts and data buffers. A library of C language call routines for implementing the communication is included – but this where the product falls short. Although the user manual is detailed, it has a typical dictionary format - definition of function, what it does but no example of how to use it. So new users are presented with a massive amount of information and no guide.

For example in chapter six there is a section entitled "driver function summary". But it is only after working with the product for a long time that we learn that the functions refer to the "Janus" monitor.

The user is presented with a long list of F functions with no description of where they come from or how to use them.

What is so often forgotten by writers of manuals is that their documents are read by users wanting to learn how to use the product, and the most efficient way of learning is through example. In an otherwise superb product the number of learning examples really is inadequate.

Full access to the DSP96002

Both boards are well engineered pieces of hardware, giving users access to the full potential of the DSP96002.

The MM-96 is a very high performance systems board, capable of some impressive number crunching, and its dual DSP96002 processor design makes it suitable for parallel processing applications. For investigating the capabilities of the DSP96002 as a high performance processor the MM-96 is eminently suitable as a hardware platform and is quite excellent in its design.

But it is quite conceivable that many potential applications will be coded in C and not in assembly language to any great extent: there should be more examples to assist this requirement.

My main reservations concern the lack of an appropriate high-level-language user-interface for users who wish to program exclusively in C, and the steep learning curve, not helped by the absence of short illustrative examples in the user manual.

The LSI DSP96002 board is also a top quality product, lending itself particularly well to real-time processing with its integral A-to-D/D-to-A facility. It is ideally suited for applications where high speed signal processing is required, and for this the DSP96002 would be programmed in assembler; View96 software is a great bonus for monitoring the processor board.

Many examples throughout the accompanying manuals provide valuable insights into operation of the board, enabling users to gain a fast working knowledge of the product.

The complete LSI package is a very pleasing product to work with and is highly recommended as a DSP96002 processing development platform. ■

SUPPLIER DETAILS

LSI DSP96002 board £3795 + VAT Loughborough Sound Images, TheTechnology Centre, Epinal Way, Loughborough, Leics LE11 0QE (0509-231843)

Ariel MM-96 £4900 + VAT. Data Beta Ltd. Unit 7, Chiltern Enterprise Centre, Theale, Berkshire. RG7 4AA (0734-303631)

CIRCUIT DESIGN WITH THE INTERACTIVE TOUCH

Impressive simulation, control of device characteristics and an ideal companion to Pspice: Allen Brown finds out why LogicWorks could be such a powerful aid for digital designers.

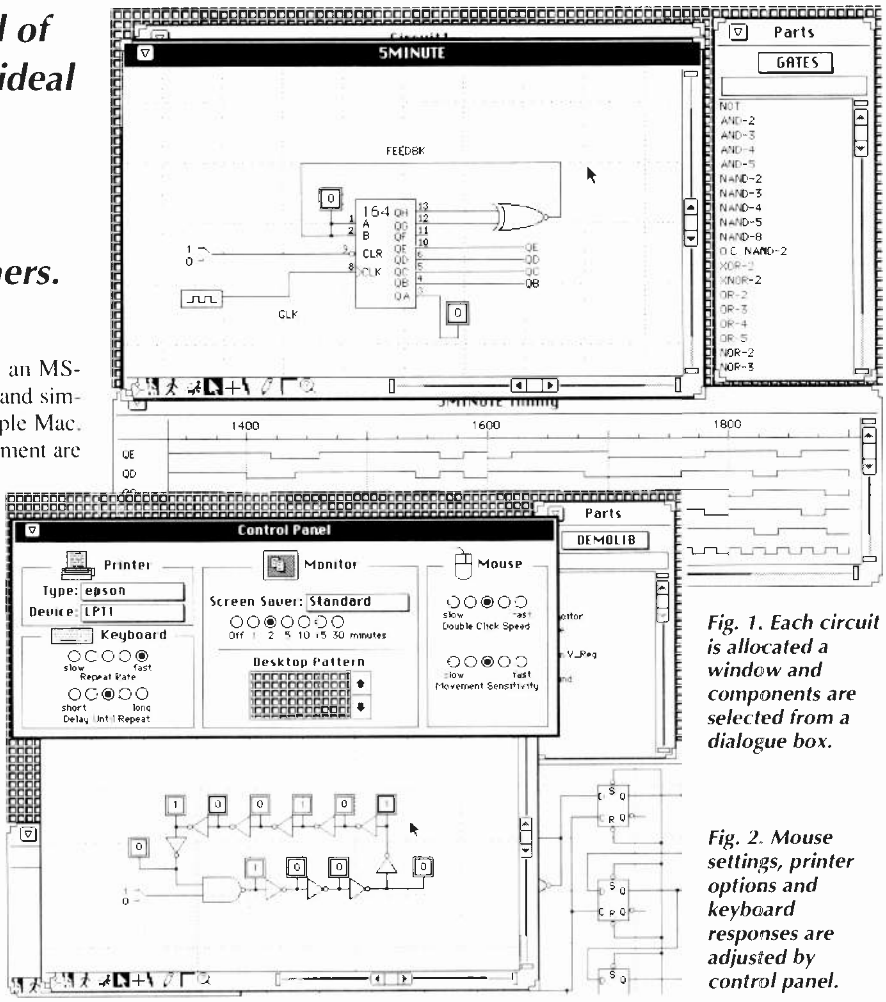


Fig. 1. Each circuit is allocated a window and components are selected from a dialogue box.

Fig. 2. Mouse settings, printer options and keyboard responses are adjusted by control panel.

Capilano Computing of Canada has launched an MS-Dos version of LogicWorks, its logic design and simulation package originally issued for the Apple Mac. Many features common to the Mac graphics environment are retained so that the new version is a comprehensive windows-based, digital design facility, fully user-interactive. The now well-known graphics user interface (GUI) underlies the package and allows the user to interact with the PC through mouse clicking and dragging.

In use, each circuit is allocated a window (**Fig. 1**), and several windows/circuits can be operational at any one time – complexity is only limited by extended memory available in the PC.

Size and shapes of each window can be adjusted by using the mouse click and drag and each circuit window is allocated a simulation strip chart, or timing diagram, for the circuit.

Options are accessed through the right button on the mouse, generating a sequence of dialogue boxes allowing the appropriate selection to be made. Circuit components are chosen from the parts library, accessed through the window located on the top right of the screen (Fig. 1).

Libraries – and eye strain?

At the base of each circuit window there are ten icons and these control the speed of simulation and the general schematic control over the component entries such as labelling and device orientation. When the mouse is clicked on one of the icons it assumes its identity – a useful facility for editing circuits and a good example of the powerful interactive aspects of the package.

For example, if a simulation of a node is required, picking up the pen icon allows a label to be attached to the node and neatly generates the same label in the simulation timing diagram

Several groupings are included in the libraries. But as yet the 74 series library is rather thin with many notable holes - the 74373 octal latch and 74245 octal transceiver to name just two.

How many logic designs do not contain 373s? Before LogicWorks can become really useful for design this library must be improved, though Capilano does promise that libraries are frequently updated.

The Gates library on the other hand offers a large selection of logic gates which are referred to as primitives.

But an irritating feature common to all the libraries is the difficulty experienced in trying to retrieve a component. A double click on the mouse is required and usually a couple of

SYSTEM REQUIREMENTS
IBM (clone) AT 386 or 486 PC
4Mbyte extended memory
VGA monitor
Microsoft mouse

attempts need to be made before the device is captured. Fortunately the problem can be alleviated to some extent by adjusting the timings on the mouse in the control panel (Fig. 2).

Once a device has been captured, any number of copies can be implanted in the drawing area. But the optimum mouse speed must be found as the wrong mouse setting can cause difficulties when making connections between contacts on devices.

One of the few problems of using a PC with LogicWorks for circuit design is the limitation of the 14in monitor screen. After a while it can seem a strain on the eyes, though this is part of the price that must be paid for running graphically intensive application programs on economy PCs. Even so, LogicWorks circuit diagrams can be stored as image files for desk top publishing packages.

For hard copies, four families of printers are supported, PostScript, Epson, LaserJet and HP DeskJet.

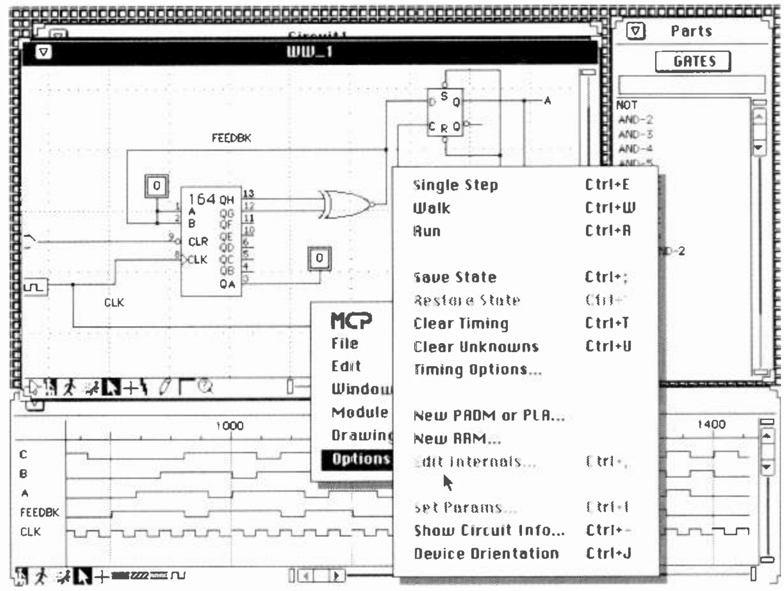


Fig. 3. LogicWorks options menu.

Impressive simulation

One of the strong features of LogicWorks is simulation, coming in the form of the timing diagram at the base of the screen. Each labelled node will have an automatic entry in the simulation diagram and a particular strength of the product is the ability to adjust the propagation delay of each gate or device.

A timing diagram in itself is not particularly novel. But the opportunity to vary the gate propagation delays is very welcome. By highlighting a gate (a single mouse click) and accessing the SET PARAMS in the options menu (**Fig. 3**), the propagation delay dialogue box is reached, **Fig. 4**.

The results of adjusting the propagation delays appear in the circuit timing diagram. Or the clock skew can be adjusted, again via a dialogue box, and the results can be seen at the bottom half of the screen, **Fig. 5**. There is also the opportunity to change, interactively, any signal level in the timing diagram, with the overall effect instantly showing up on the other timing waveforms directly affected. Added together the capabilities make simulation an impressive part of the LogicWorks package.

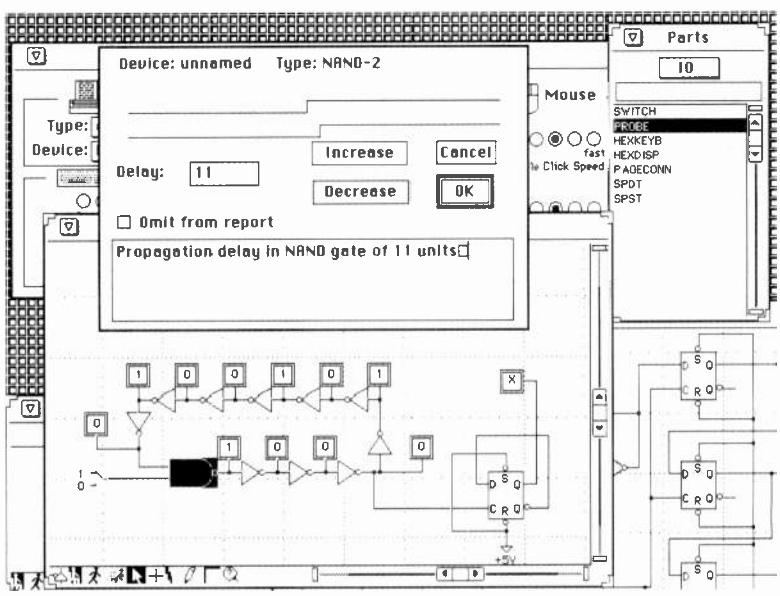


Fig. 4. Propagation delays can be adjusted in highlighted components.

Fig. 5. Simulation diagram showing designer clock skew.

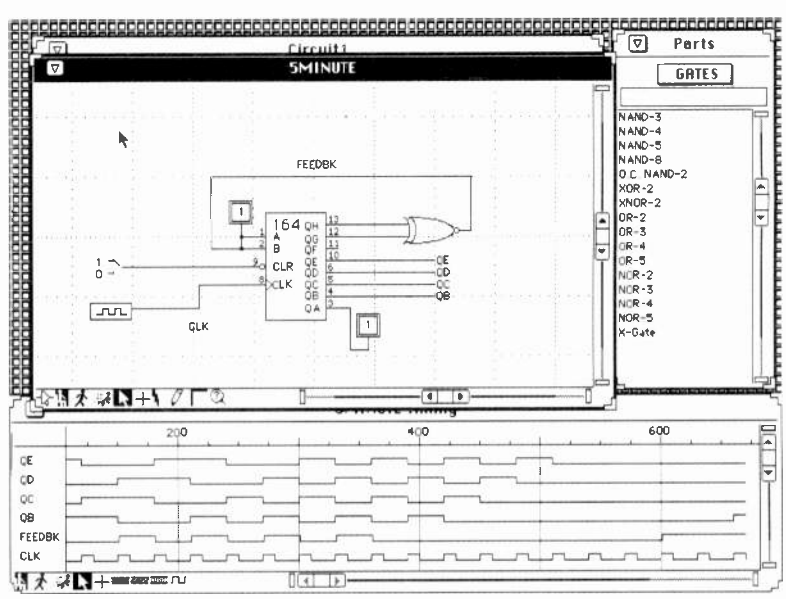
When a hard copy of the timing diagram is require the print option is evoked and quite a respectable print-out is produced even from a 9-pin matrix printer.

Spice netlist

Spice has become the *defacto* standard for analogue simulation. So it is good to see LogicWorks' facility for creating Spice netlists. Analogue circuits can be created by schematic entry on LogicWorks (**Fig. 6**) and the devices required for their construction can be found in the DISCRETE library (**Fig. 7**). DISCRETE really is a full list components; if only the other libraries were so well stocked.

Each device in a Spice netlist requires a set of component parameters, defined by highlighting the device with a mouse click and then opening up dialogue box where the device attributes or parameters can be entered. The technique is simple and takes very little learning by anyone familiar with a Spice. The REPORT option allows a created text field to be rendered suitable for importing directly into a Spice package (Pspice for example).

For the creative designer, LogicWorks' device editor – a complete object-oriented environment with a set of standard



SMALL SELECTION ONLY LISTED – EXPORT TRADE AND QUANTITY DISCOUNTS – RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK

Tektronix 475 – 200Mc/s oscilloscopes – tested from £400 less attachments to £500 C/W manual probes.
Marconi TF2008 – AM-FM signal generator – Also sweeper – 10Kc/s – 510Mc/s – from £350 tested to £500 as new with manual – probe kit in wooden carrying box.
HP DC Current source type 6177C – £200.
HP Frequency comb generator type 8406A – £400.
HP Sampling Voltmeter (Broadband) type 3406A – £200.
HP Vector Voltmeter type 8405A – £400 to £600.
HP Synthesiser/signal generator type 8672A – 2 to 18GHzS old or new colour £4000.
HP Oscillographic recorder type 7404A – 4 track – £350.
HP Plotter type 9872B – 4 pen – £300.
HP Sweep Oscillators type 8690 A & B + plug-ins from 10Mc/s to 18GHz also 18-40GHz. P.O.R.
HP Signal Generators type 612 – 614 – 618 – 620 – 628 – frequency from 450Mc/s to 21GHz.
HP Network Analyser type 8407A + 8412A + 8601A – 100Kc/s – 110Mc/s – £500–£1000.
HP 432A–435A or B Power Meters + Powerheads – 10Mc/s–40GHz – £200–£650.
HP Down Converter type 11710B – .01-11Mc/s – £450.
HP Pulse Modulator type 11720A – 2-18GHz – £1000.
HP Modulator type 8403A – £100-£200.
HP Pin Modulators for above-many different frequencies – £150.
HP Counter type 5342A – 18GHz – LED readout – £1500.
HP Signal Generator type 8640B – Opt001 + 003 – .5-512Mc/s AM/FM – £1200.
HP Spectrum Display type 3720A £200 – HP Correalator type 3721A £150.
HP 37555 + **3756A** – 90Mc/s Switch – £500.
HP Amplifier type 8447A – .1-400Mc/s £400 – HP8447F .1-1300Mc/s £800.
HP Frequency Counter type 5340A – 18GHz £1000 – rear output £800.
HP 8410 – A – B – C Network Analyser 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.
HP Signal Generator type 8660C – .1-2600Mc/s. AM/FM – £3000. 1300Mc/s £2000.
HP Signal Generator type 8656A – 0 1-990Mc/s. AM/FM – £2250.
HP 3730B Mainframe £200.
HP 8699B Sweep PI – 0.1-4GHz £750 – HP8690B Mainframe £250.
HP Digital Voltmeter type 3456A – £900.
Racal/Dana digital multimeter type 5001 – £250.
Racal/Dana Interface type 9932 – £150.
Racal/Dana GPIB Interface type 9934A – £100.
Racal/Dana 9301A-9303 RF Millivoltmeter – 1.5-2GHz – £350-£750.
Racal/Dana Counters 9915M – 9916 – 9917 – 9921 – £150 to £450. Fitted FX standards.
Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
Racal – SG Brown Comprehensive Headset Tester (with artificial head) Z1A200/1 – £450.
EIN 310L RF Power Amp – 250KHz – 110Mc/s – 50Dbs – £250.
Marconi AF Power Meter type 893B – £300.
Marconi Bridge type TF2700 – £150.
Marconi/Saunders Signal Sources type – 6058B – 6070A – 6055B – 6059A – 6057B – 6056 – P.O.R. 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.
Marconi distortion meter type TF2331 – £150. TF2331A – £200.
Thurlby convertor 19 – GP – IEEE – 488 – £150.
Philips logic multimeter type PM2544 – £100.
Microwave Systems MOS/3600 Microwave frequency stabilizer – 1 to 18GHzs & 18 to 40GHzs – £1000.
Bradley Oscilloscope calibrator type 156 – £150.
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 – P.O.R.
Ailtech Stoddart receiver type 17/27A – .01-32Mc/s – £2500.
Ailtech Stoddart receiver type 37/57 – 30-1000Mc/s – £2500.
Ailtech Stoddart receiver type NM65T – 1 to 10GHz – £1500.
Gould J3B Test oscillator + manual – £200.
Image Intensifiers – ex MOD – tripod fitting for long range night viewing – as new – £1500-£2000.
Don 10 Telephone Cable – ½ mile canvas containers or wooden drum – new – Mk2-3 or 4.
Infra-red Binoculars in fibre-glass carrying case – tested – £100. Infra-red AFV sights £100.
ACL Field intensity meter receiver type SR – 209 – 6. Plugs-ins from 5Mc/s to 4GHz – P.O.R.
Systron Donner Counter Model 6057 – 18GHz – £800.
Tektronix 491 spectrum analyser – 1.5GHz-40GHz – as new – £1200 or 10Mc/s 40GHz.
Tektronix Mainframes – 7603 – 7623A – 7633 – 7704A – 7844 – 7904 – TM501 – TM503 – TM506 – 7904 – 7834 – 7104.
Knott Polyskanner WM1001 + WM5001 + WM3002 + WM4001 – £500.
Ailtech 136 Precision test RX + 13505 head 2 – 4GHz – £350.
SE Lab Eight Four – FM 4 Channel recorder – £200.
Ailtech 757 Spectrum Analyser – 001 22GHz – Digital Storage + Readout – £5000.
Dranetz 606 Power line disturbance analyser – £250.
Precision Aneroid barometers – 900-1050Mb – mechanical digit readout with electronic indicator – battery powered. Housed in polished wood carrying box – tested – £100-£200-£250. 1, 2 or 3.
B & K Sound Level Meter type 2206 – small – lightweight – precision – ½" microphone – in foam protected filled brief type carrying case with windshield & battery + books + pistol grip handle – tested – £170. Carr. £8. – B & K 2206 Meter + Mike + Book – less carrying case etc. – £145. Carr. £8. **DISCOUNT ON QUANTITY**
HP 141T Spectrum Analysers. All new colours supplied with instruction manuals.
HP 141T-8552B – 8556A – 20Hz to 300kHz. £2000.
HP 141T-8552B – 8553B – 1kHz to 110Mc/s. £1750.
HP 141T-8552B – 8554B – 100kHz to 1250Mc/s. £2250.
HP 141T-8552B – 8555A – 10Mc/s to 18GHz. £3000.
HP 141T – old colour mainframe + 8552A; 8553B – 1kHz to 110Mc/s. Instruction manuals – £1250 or 8552B £1500.
HP 3580A LF-spectrum analyser – 5kHz to 50kHz – LED readout – digital storage – £1600 with instruction manual – internal rechargeable battery.
Spectrascope 11 SD335 (S.A.) realtime LF analyser – 20Hz to 50kHz – LED readout with manual – £500 tested.
Tektronix 7D20 plug-in 2-channel programmable digitizer – 70 Mc/s – for 7000 mainframes – £500 – manual – £50.
Datron 1065 Auto Cal digital multimeter with instruction manual – £500.
Racal MA 259 FX standard. Output 100kc/s–1Mc/s–5Mc/s – internal NiCad battery – £150.
Tektronix TR503 tracking generator – 10Mc/s to 1800Mc/s + manual – £1500.
Aerial array on metal plate 9"×9" containing 4 aerials plus Narda detector – .100–11GHz. Using N type and SMA plugs & sockets – ex eqpt – £100.
EIP 451 microwave pulse counter 18GHz – £1500.
Marconi RF Power Amplifier TF2175 – 1.5Mc/s to 520Mc/s with book – £100.
HP 8614A Signal Generator 800Mc/s to 2.4GHz – old colour – £300. New colour – £600.
HP 8616A Signal Generator 1.8GHz to 4.5GHz – old colour – £200. New colour – £400.
HP 8620A or 8620C Sweep Generators – £400 or £900.
Marconi 6155A Signal Source – 1 to 2 GHz – LED readout – £600.
Schlumberger 2741 Programmable Microwave Counter – 10Hz to 7.1GHz – £750.
Schlumberger 2720 Programmable Universal Counter 0 to 1250Mc/s – £600.
HP 37203A HP-IB Extender – £150.
PPM 411F Current Reference – £150.

HP 5363B Time Interval Probes – £150.
HP 8900B Peak Power Calibrator – £100.
HP 59313A A/D Convertor – £150.
HP 59306A Relay Actuator – £150.
HP 2225CR Thinkjet Printer – £100.
TEK 178 Linear IC Test Fixture – £150.
TEK 576 Calibration Fixture – 067-0597-99 – £250.
HP 4437A 600 Ohm Attenuator – £100.
HP 8006A Word Generator – £150.
HP 1645A Data Error Analyser – £150.
Texscan Rotary Attenuators – BNC/SMA 0-10-60-100DBS – £50-£150.
HP 809C Slotted Line Carriages – various frequencies to 18GHZ – £100 to £300.
HP 532-536-537 Frequency Meters – various frequencies – £150-£250.
HP 3200B VHF Oscillator – 10MC/S-500MC/S – £200.
Barr & Stroud variable filter EF3 0.1Hz–100kc/s + high pass + low pass – mains – battery – £150.
Krohn-Hite Model 3202R filter – low pass, high pass.
Krohn-Hite 4100 oscillator.
Krohn-Hite 4141R oscillator – .1Hz–10,000kHz.
Krohn-Hite 6880 programmable distortion ANZ-IEEE-488.
Krohn-Hite 3750 filter, low pass, high pass – .02Hz–20kHz.
Parametron D150 variable active filter, low pass – high pass – 1.5Hz–10kHz. £100.
S.E. Lab **SM215** Mk11 transfer standard voltmeter – 1000 volts.
Fluke 4210A programmable voltage source.
Ailtech Stoddart P7 programmer – £200.
Fluke 8500A digital multimeter.
H.P. 3490A multimeter.
H.P. 6941B multiprogrammer extender. £100.
Fluke Y2000 RTD selector + Fluke 1120A IEEE-488-translator + Fluke 2180 RTD digital thermometer + 9 probes. £350 all three items.
H.P. 6181 DC current source. £150.
H.P. 59501A – HP-IB isolated D/A/power supply programmer.
H.P. 3438A digital multimeter.
H.P. 61775 DC current source.
H.P. 6207B DC power supply.
H.P. 741B AC/DC differential voltmeter standard (old colour) £100.
H.P. 6209B DC power unit.
Fluke 80 high voltage divider.
Fluke 887AB AC+DC differential voltmeter.
Fluke 431C high voltage DC supply.
H.P. 1104A trigger countdown unit.
Tektronix M2 gated delay calibration fixture. 067-0712-00.
Tektronix precision DC divider calibration fixture. 067-0503-00.
Tektronix overdrive recovery calibration fixture. 067-0608-00.
Avo VCM163 valve tester + book £300.
H.P. 5011T logic trouble shooting kit. £150.
Marconi TF2163S attenuator – 1GHz. £200.
PPM 8000 programmable scanner.
H.P. 9133 disk drive + 7907A + 9121 twin disk.
Fluke 730A DC transfer standard.
B&K level recorder 2307 – £500.
B&K 2113 audio frequency spectrometer – £150.
B&K 4815 calibrator head.
B&K 4812 calibrator head.
B&K 4142 microphone calibrator – £100.
B&K 1022 band FX oscillator – £100.
B&K 1612 band pass filter set – £150.
B&K 2107 frequency analyser – £150.
B&K 1013 BFO – £100.
B&K 1014 BFO – £150.
B&K 4712 FX response tracer – £250.
B&K 2603 microphone amp – £150.
B&K 2604 microphone amp – £200.
B&K 2019 analyser – £350.
Farnell power unit H60/50 – £400 tested.
H.P. FX doubler 938A, also 940A – £300.
Racal/Dana 9300 RMS voltmeter – £250.
A.B. noise figure meter 117B – £400.
Ailtech 360D11+3601+3602 FX synthesizer 1Mc/s–2000Mc/s. £500.
H.P. sweeper plug-ins – 86240A – 2–8.4GHz – 86260A – 12.4–18GHz – 86260AH03 – 10–15GHz – 86290B – 2–18.6GHz. 86245A 5.9–12.4GHz.
Telequipment CT71 curve tracer – £200.
H.P. 461A amplifier – 1kc–150Mc/s – old colour – £100.
H.P. 8750A storage normalizer.
Tektronix oscilloscopes type 2215A – 60Mc/s – c/w book & probe – £400.
Tektronix monitor type 604 – £100.
Wiltron 560 network scaler + 2 heads + book – £1000.
Marconi TF2330 or TF2330A wave analysers – £100–£150.
HP5006A Signature Analyser £250 + book.
HP10783A numeric display. £150.
HP239A oscillator – £250.
Ailtech 7009 hot–cold standard noise generator.
HP 3763A error detector. £250.
Cushman CE-15 spectrum analyser – LED Readout – 1000Mc/s £650.
Tektronix 5L4N spectrum analyser – 0–100kc/s £500.
HP1742A 100Mc/s oscilloscope. £250.
HP1741A 100Mc/s oscilloscope. £250.
Tektronix 7104–7A29–7A24–7B15–7B10 – £2K.
Racal/Dana signal generator 9082 – 1.5–520Mc/s – £800.
Racal/Dana signal generator 9082H – 1.5–520Mc/s – £900.
Claude Lyons Compuline – line condition monitor – in case – LMP1 + LCM1 £500.
HP1815B T.D.R. sampler + 1817A head – 1104A trigger + 1106B TD mount £500.
Texscan AL-51A spectrum analyser – 4–1000Mc/s – £750.
Efratom Atomic FX standard FRT – FRK – 1–1–5–10Mc/s. £3K.
Muirhead fax receivers K649 – TR4 – solid state – speed – 60–90–120–240–auto – IC 288-576 – auto. £250 with book.
Racal 4D recorder – £350.
HP8350A sweep oscilloscope mainframe + HP11869A RF PI adaptor – £2.5K.
Ailtech – precision automatic noise figure indicator type 75 – £250.
Adret FX synthesizer 2230A – 1Mc/s. £250.
Tektronix – 7S12–7S14–7T11–7S11–S1–S52–S53.
Rotek 610 AC/DC calibrator. £2K + book.
Tektronix 7L12 analyser – 1Mc/s–1.8GHz. £1500.
Clark Scam Heavy Duty 40' Telescopic Pneumatic Masts – retracted 7'8" – head load 40lbs – with or without supporting legs & erection kit – in bag + handbook – £200-£500.
Clark Scam Heavy Duty 70' Telescopic Pneumatic Masts – retracted 13'5" – head load 90lbs – with or without legs + erection kit + handbook – £500-£800.

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CIRCLE NO. 130 ON REPLY CARD

cad drawing tools – enables schematic symbols to be constructed. Symbols can be used with great effect in constructing devices for analogue circuit design, and, by using the report generator, the appropriate parameters can be attached to devices.

PLA and prom power

The facility to allow design of PLAs and proms is another very attractive feature of LogicWorks. Starting point is definition by the user of the number of inputs, outputs and the respective truth table. The new prom or PLA option can then be entered in a dialogue box, specifying the number of device inputs, outputs and device propagation delay. By clicking the SPECIFY OUTPUTS box another box opens to enable entering of the contents truth table.

LogicWorks can also read in device data files derived from logic minimisation programs (Palasm for example). But a dedicated library of standard PLA devices in which the PLA design could be implemented would be a bonus. The PLA design option is certainly useful but does require an external minimisation software product to renderer it totally effective.

Report generation

If a text file needs to be attached to any circuit or simulation LogicWorks' report generator can be used (**Fig. 8**). At the top of the dialogue box there are four buttons: SIGNALS will produce a netlist file containing all the information on the signal sources in the diagram; DEVICES produces a file listing all devices in the circuit, sorted by name followed by device type name as it appears in the DEVICES menu; TYPE allows the user to generate a file, listing the type name (parts list) and quantity used in the design - a useful feature for costing the design; SPICE, as previously mentioned, produces a netlist file suitable for a Spice package. Users can choose to omit an item from a file list by clicking on the option in the SET PARAMS command.

Well designed partner for Pspice

On the whole, LogicWorks is well designed and a useful tool for designers, with many attractive features and a comfortable feel. Often, when using a package of this complexity, there is a strait-jacket feeling, the software imposing its restrictions on the user. But with LogicWorks there is no sense of this restriction and the package can honestly be described as user friendly.

Its level of simulation combined with the option to change device characteristics makes it a powerful working aid for digital designers. In many respects it is an ideal companion to work alongside Pspice – LogicWorks creating the circuit diagrams and netlists, and Pspice providing analogue simulation. Relatively low cost of the package will widen its appeal to users, and once the libraries are stocked up I would have no hesitation in recommending it as a serious design tool. ■

SUPPLIER DETAILS
Calandown Ltd, 96 High Road, Byfleet, Surrey. KT14 7QT 0932-342137 Cost £300.

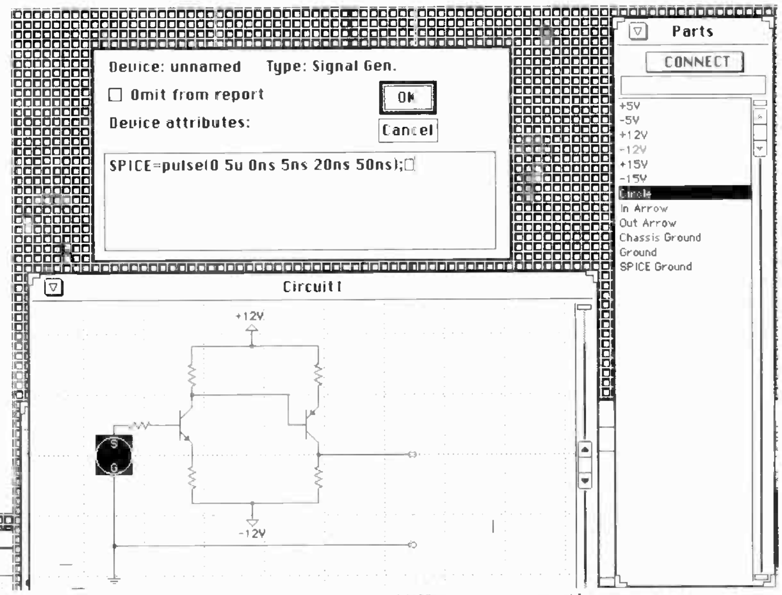


Fig. 6. Analogue circuits can be created by LogicWorks.

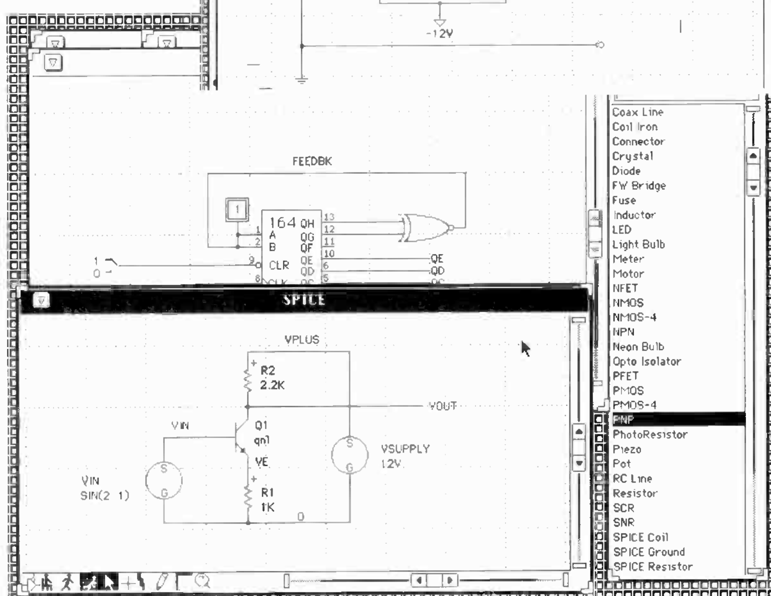


Fig. 7. Device library is well stocked and should provide a model for LogicWorks' other libraries.

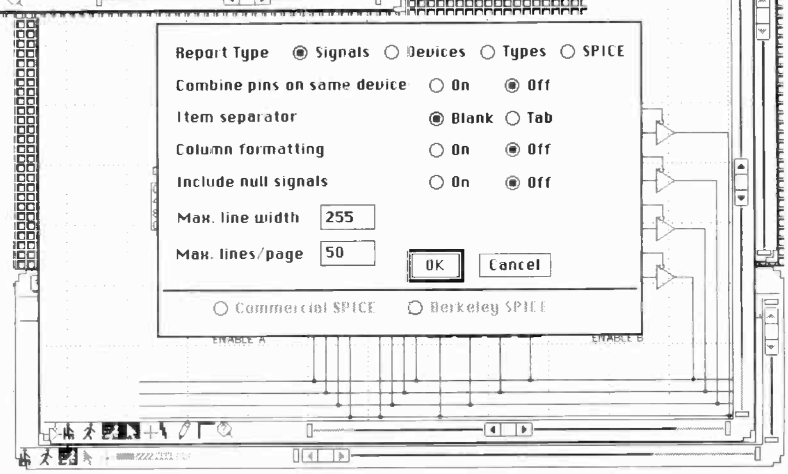


Fig. 8. Four options for file formats, produced by the report generator.

USER MANUAL THAT YOU CAN REALLY USE

A reasonable amount of effort has been spent in design of the wire-spine user-manual. Not only has Capilano capitalised on DTP techniques to highlight product features but it has also provided good, clear descriptions throughout the manual. Illustrations are generous, with many screen displays, and the text is obviously written with the end-user in mind. Capilano has practised the golden rule manual writing – learn by example. There are lots of examples complete with the all-important "getting started" section.

Chapter three launches the user into a tutorial, with step by step working examples – ideal for establishing a new user's confidence in the product.

All in all the LogicWorks manual is a credit to Capilano.

STRUCTURED ANALOGUE DESIGN BUILDS PERFECT FILTERS

Every so often, an entirely novel idea in electronics emerges. A filter based on simple, highly structured building blocks can produce brick wall filtering performance allied with zero phase shift. The principles for doing this digitally are well known. Professor David Grundy's topology works completely in the analogue domain.

The November 1991 edition of *Electronics World* carried an article on the principles of structured analogue electronics. It described a system which could perform temperature independent mathematical operations such as multiplication, division and raising to a power. This article applies the technique to producing a new type of filter which, in addition to being highly geared to design by CAD tools also offers improved performance, particularly in terms of a dramatic reduction in the number of reactive components. Furthermore, there is no phase shift through the filter.

Filtering state of the art

Monolithic filters can be broadly classified into one of three types: active filters based upon operational amplifiers which are obviously analogue in nature and are classified into types such as Butterworth Chebyshev and Bessel.[1] The choice of filter employed from the options depends upon such factors as the degree of ripple tolerable in the passband, allowable phase shift and transient response. As always a compromise in performance is inevitable. A characteristic of this type of filter is that the higher the order, the larger the number of reactive components required which for monolithic filters clearly means capacitors. If inductors are required then one can turn to gyrators which effectively invert the frequency dependent reactance of a capacitor to provide a component similar to an inductor, ie its reactance increases with frequency. There are other circuit tricks such as negative impedance converters which can also transform the reactive behaviour of a capacitor; for reasons of sensitivity they seem to have declined in popularity. Whatever the filter configuration chosen, designing a filter of this type proceeds at the component level and most commonly uses standard forms.

The second type of filter is that based upon the principles of switched capacitors[2]. This principle arose as a result of the components available to the designer in mos technology i.e. no resistors but good quality well matched capacitors and transistors which act as switches. A combination of switches and capacitors can be made to behave like a resistor and hence accurate time constants can be produced from which filter networks may be assembled.

This type of filter is usually the first choice for telecomms.

Digital filters implemented with DSP are the third type. In this situation the analogue signal is first converted into digital form by a combination of sample/hold function and A to D converter. Following this samples of the signal are taken at discrete and uniformly spaced intervals.

A sequence of algorithms such as convolution are then applied; these involve multiplying successive samples by weighted coefficients: adding and then accumulating the result. The resulting filtering profile is determined by the values of the weighting coefficients. Before being of value to the real world this digital processing procedure must be followed by digital to analogue conversion.

Reviewing analogue action

Active filters based upon operational amplifiers are simple and as such do not suffer from effects such as aliasing distortion. On the negative side they suffer from phase distortion which, while of little significance for most speech applications, is of great importance in data processing where severe signal distortion can occur as a result of variations in delay seen by different frequencies passing through the filter. Additionally, higher order filters are difficult through sheer quantity of reactive elements required.

Switched capacitor types have the advantage of low current consumption although their design is highly specialised. They also suffer from aliasing distortion. This means that if the input signal has any components near to the clock frequency they will be aliased down into the pass band.

Digital filters in theory have greatest flexibility since they do not rely upon the properties of electrical networks and will carry out any processing procedure defined by the installed algorithms. Design can be difficult however and sometimes it is necessary to translate known analogue filters into their digital equivalent using a procedure known as pre-warping. Again DSP design skills are scarce although becoming more widespread as the technology gains momentum. As for switched capacitor, signal components near to clock frequencies can produce aliasing distortion since digital filters are not time continuous by nature. Digital filters require a relatively massive chip area due to their complexity and this has cost implications..

Structured analogue filters

The underlying principle of SAE states that all analogue processing problems can be solved with a short set of basic instructions similar to those associated with digital computers. The design process then becomes one of establishing equations for the desired system function then solving these with the functional building blocks of SAE. While there are many possibilities for the instruction repertoire.

Logarithms: do it with diodes

Analogue designers generally struggle to remove distortion caused by the non-linear transfer characteristics of active devices. The first step is to bias the device into its most linear region and the second – usually – is to apply negative feedback. If instead of using negative feedback, etc, to linearise junction characteristics, we take a closer look at the fundamental properties, then a few surprises are in store.

The basic relationship for current and voltage, associated with any semiconductor junction is given by:

$$I = I_o \exp\frac{qV}{nkT} \quad \text{or} \quad V = \frac{nkT}{q}\ln\frac{I}{I_o}$$

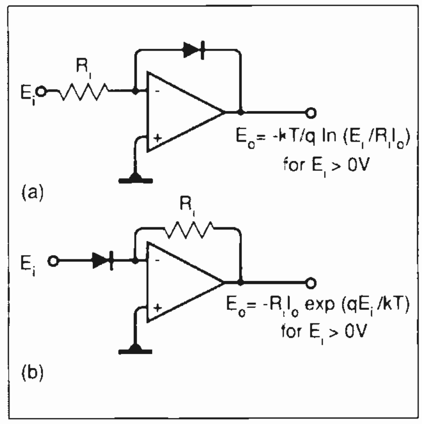
where I = forward conduction current, >> I_o; I_o = reverse saturation current; q = charge on electron; V = voltage across the junction; n = a constant near unity; k = Boltzmann's constant; T= absolute temperature. This equation holds true for all semiconductor junctions whatever the technology, be it bipolar, cmos or bicmos and also for all materials, silicon, germanium or gallium arsenide.

A further important attribute is its remarkable consistency, that is at least for silicon. This is due in part to the fantastic amount of effort and money that has been spent on bringing silicon to its present state of refinement. A long lasting experience of this diode equation and information gathered from other sources has shown that the equation shown above is typically accurate to 1% over at least eight decades of current.

Further to this, junctions in n-p-n transistors with high values of hfe connected as diodes (V_{cb} = 0V) have been seen operating down to 10^{-14} amps. The log diode equation can thus be used confidently in predictable analogue design.

The basic logarithmic behaviour of semiconductor junctions (when not being linearised) is currently used in multipliers, AGC circuits, etc. However, it is not applied consistently and often the wheel is re-invented with each new application. Also, the division capabilities of p-n junctions are often not fully appreciated.

SAE involves the extensive use of logarithms. If instead of linearising the exponential behaviour of a p-n junction, one simply converts signals into logarithmic form by use of this fundamental and consistent characteristic, then a great number of problems disappear. Multiplication for example can be achieved simply by addition of logarithms, division by subtraction and raising to a power by multiplication of the logarithm by the required exponent.



(a) Logarithmic amplifier with junction connected into negative feedback loop; (b) antilog amplifier.

experience has resulted in the establishment of the following:

1 ADD	Addition
2 NOT	Inversion
3 LOG	Logarithm
4 ALOG	Antilogarithm
5 AMP	Amplify
6 DIFF	Differentiation
7 INT	Integration

These seven instructions will solve a very wide range of analogue design problems ranging from precision voltage reference sources to high performance filters. Turning now specifically to filters, designing with SAE always starts with an equation. The role of a filter is of course to define the manner in which the transfer function of a system varies with respect to frequency. The Butterworth filter to which we referred to earlier is characterised by the equation:

$$E_{out} / E_{in} = \frac{1}{\sqrt{1+(f/f_c)^{2n}}}$$

If we are to attack the problem as an equation solving exercise and forget about the traditional bottom up method – where one seeks to find an electrical network/amplifier combination with the required behaviour with respect to frequency – then it is necessary to isolate the frequency terms out of the signal equation. Having done this they can then be placed in an equation along with other terms to define the prescribed filter behaviour; SAE techniques may then be applied to implement this equation.

Let's start with a basic sinusoidal signal given by:

$e = E_o \sin\omega t$

If we differentiate this once (instruction 6) we obtain:

$de/dt = E_o\omega\cos\omega t$

If we differentiate a second time (instruction 6 again) then we obtain:

$d^2e/dt^2 = -\omega^2 E_o \sin\omega t$

If this is now inverted (instruction 2) then we obtain:

$$-d^2e/dt^2 = \omega^2 E_o \sin\omega t$$

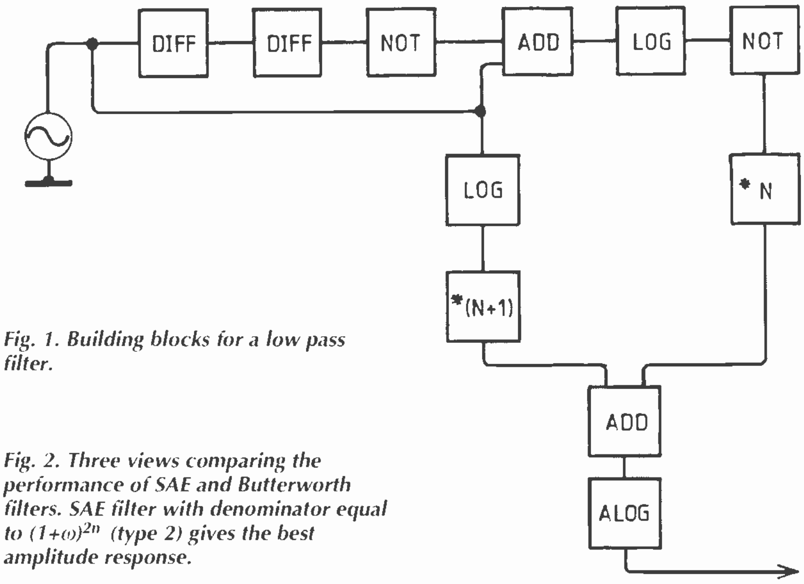
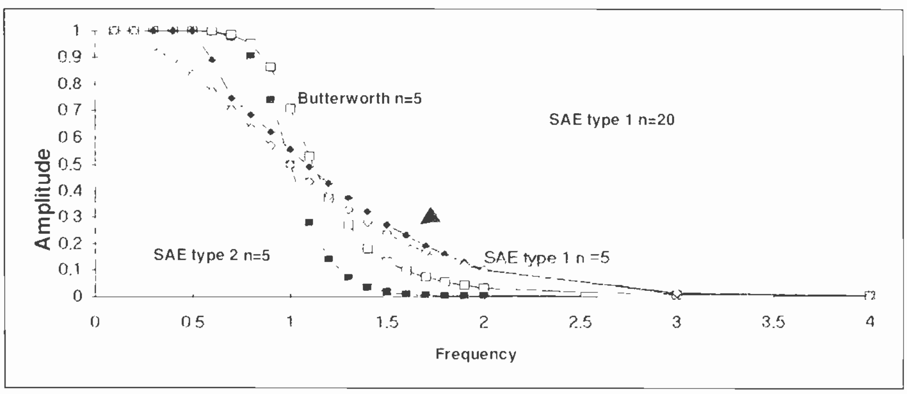
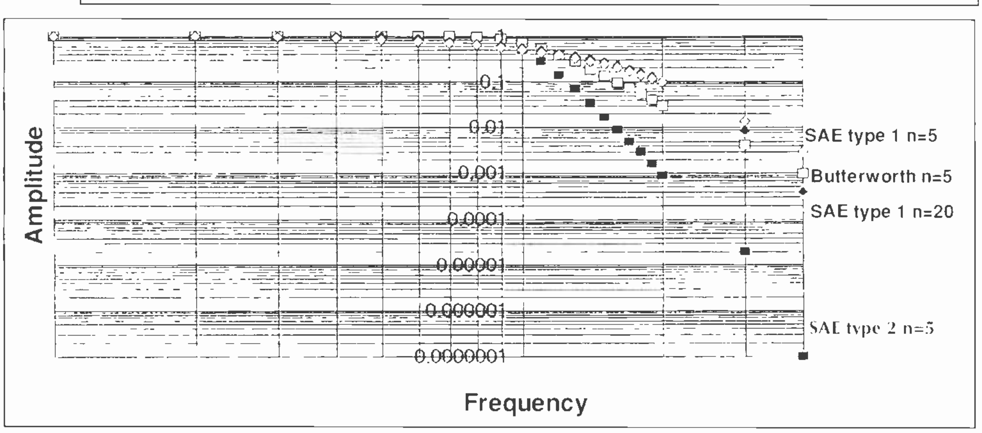


Fig. 1. Building blocks for a low pass filter.

Fig. 2. Three views comparing the performance of SAE and Butterworth filters. SAE filter with denominator equal to $(1+\omega)^{2n}$ (type 2) gives the best amplitude response.





the techniques are equally applicable to high pass, band pass, notch or indeed any configuration which can be mathematically described.

First of all a very general form of low pass filter (now referred to as type 1) can be expressed as:

$$V_{out} / V_{in} = \frac{1}{(1+\omega)^n}$$

It will make things easier to implement if we allow ω to become squared

$$V_{out} / V_{in} = \frac{1}{(1+\omega^2)^n}$$

This is not a restriction since we are looking for higher orders of filter anyway. Once again, for ease of implementation, this equation can be rewritten as:

$$V_{out} = \frac{V_{in}}{(1+\omega^2)^n}$$

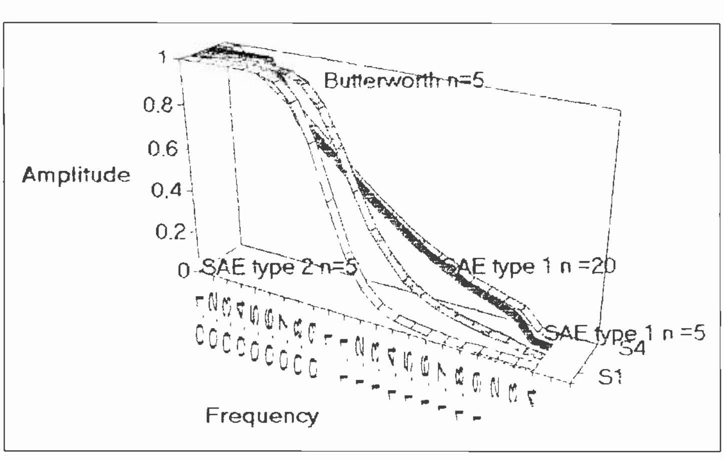
This may seem to be laborious and pedantic but it will be seen that solving analogue signal processing equations by SAE techniques does require that they are set up in an appropriate form. The procedure is somewhat akin to the manipulative processes in calculus to facilitate integration or indeed to the similar techniques in taking inverse Laplace transforms from look up tables. The reason for substituting ω^2 for ω is that the inverted double differentiation procedure has provided us with ω information in this form.

A flat response in the pass band is provided by the unity term in the denominator and this feature must obviously be incorporated into our filter equation. Since the ω^2 term has for its coefficient the original input signal, $E_0 \sin\omega t$, it is necessary to include this as a coefficient for the unity term which also provides us with the following denominator: $E_0 \sin\omega t(1+\omega^2)$

If this term is now raised to the power of n our denominator is substantially complete except that in addition to raising $(1+\omega^2)$ to the n we have also raised $E_0 \sin\omega t$ to the n which is quite definitely not required. Unfortunately this is unavoidable and the way around it is to make the denominator also equal to $E_0 \sin\omega t$ and raise this to the power of $(n+1)$. The final equation then becomes:

This signal is of course our original signal but is now multiplied by ω^2 and is suitable for input to the SAE equation. An important point to note is that for real life signals containing many such sinewaves, there is no relative phase shift amongst them in passing through this procedure: all frequencies rotate through one full circle of 360°.

The next point to consider is how to effect the actual filtering operation. The first example depicts a low pass filter but



$$E = \frac{E_0 \sin\omega t^{n+1}}{[E_0 \sin\omega(1+\omega^2)]^n}$$

Which is of course a manipulated form of

$$E_{out} = \frac{E_0 \sin\omega t}{(1+\omega^2)^n}$$

While we have seen how to generate the frequency dependent terms, it is also clear that synthesis of the equation also requires the mathematical process of division.

In general division seems to be avoided in analogue electronics but when accurate logarithmic procedures are available (instruction 3) then the processes of multiplication and division are greatly simplified. Multiplication consists simply of adding logarithms and division involves their subtraction. Further, raising to a power can be facilitated by multiplication of the logarithm.

The means of synthesising the filter equation is now starting to become apparent. If first of all we take the logarithm of the numerator, multiply it by $(n + 1)$ and also take the logarithm of the denominator, multiply this by n and subtract it from the numerator, and finally take antilogs (instruction 4) the result is a low pass filter. A diagram might make this clearer and is shown in **Fig. 1**

First of all the input signal is fed simultaneously into the double differentiator which is part of the denominator, and also into a logarithmic converter to form the numerator. Output from the inverted double differentiator is added to the original input signal which forms the main substance of the denominator: this is also fed to a logarithmic converter.

Since the denominator must obviously be divided into the numerator, the logarithm must be inverted before adding to the logarithm of the numerator. Before the addition however the numerator log is multiplied by $(n + 1)$ which can be effected for simplicity with an amplifier (instruction 5) of fixed gain $(n + 1)$. Similarly the logarithm of the denominator can be followed by an amplifier of fixed gain n. Following addition of these terms comes the antilog operation (instruction 4). The ultimate output is the original signal which has now been subjected to low pass filtering.

A plot of the performance of this type of filter with n = 5 is shown in **Fig. 2** alongside a conventional Butterworth 5th order filter. It can be seen that the Butterworth filter is very much flatter in the passband and this is due to the fact that its denominator changes much more rapidly with frequency after the break frequency has occurred. The relevant Butterworth term is root of $(1 + \omega^{2n})$ compared with $(1 + \omega^2)^n$ for the SAE design. The addition of 1 to the ω^2 term before raising to the n in the case of the latter has caused this significant difference.

This form of equation as compared with the conventional Butterworth was chosen to simplify the hardware embodiment of the filter. If a flatter passband is required then this can be achieved by increasing the order n of the SAE filter. A plot for $n = 20$ is shown on the same axis and this is seen to offer a much flatter passband and much closer to the fifth order Butterworth. Increasing the order of an SAE filter costs nothing: it simply means multiplying the appropriate logarithms by a larger number. Eventually there could be problems with component tolerances but since we are dealing with ratios of component values within a monolithic environment this should not be a general problem.

If an even closer fit or indeed improved response when compared with the Butterworth filter is required, then this can be achieved at the expense of more complex hardware by changing the form of the denominator in the SAE filter equation. If instead of $(1 + \omega^2)^n$ we had used $(1 + \omega)^{2n}$ then the amplitude response of the SAE filter would be superior to that of the Butterworth of the same order. A plot of this function (now referred to as type 2) is also shown in Fig. 2. As commented this means an increase in the hardware complexity which is shown in its revised form in **Fig. 3**. It can be seen that instead of adding $E\sin\omega t$ and $\omega^2 E\sin\omega t$ and then raising to the power n, the two terms are now each raised to the power n separately. The ultimate equation becomes:

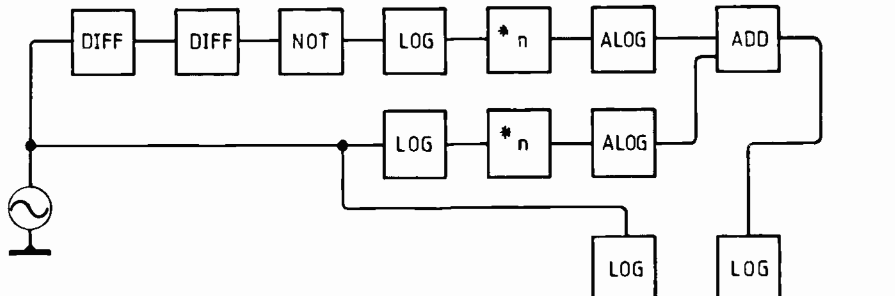
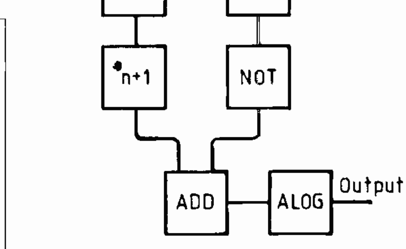
$$E_{out} / E_{in} = \frac{1}{\left(1 + \omega^{2n}\right)}$$

This is similar to the traditional Butterworth except that the square root sign has disappeared which gives a steeper slope without compromise of passband performance. Of far greater importance however is that the SAE filter has no phase shift compared with the highly non-linear phase properties of the traditional Butterworth.

If high pass, band pass, notch or indeed any other form of filter characteristic is required then, providing that this can be mathematically defined, a similar procedure of synthetic manipulation can be followed as for the low pass design.

There is however a short cut for many filters that are likely to be encountered. This possibility is due to the zero phase shift associated with this type of filter.

The particular algorithms adopted demand that the numerator and denominator are absolutely in phase and this feature turns out to have benefits other than zero phase distortion. In particular for example the output from the low pass filter can be combined in simple algebraic manner with the input signal to invert the form of the low pass filter into a high pass. This is shown in **Fig. 4** where the output from the low pass and an inverted (instruction 2) form of the input are simply added (instruction 1) to produce the high pass form of our low pass filter The break frequency is the same for each version.

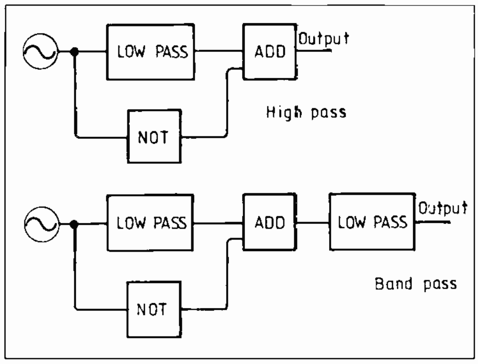


Fig. 3 (above). Achieving best SAE performance requires more complex hardware. Fig. 4. Low pass filter output can be combined with the input to invert the form into a high pass filter.

Having produced both low and high pass forms, it is relatively simple to produce band pass by cascading a high pass and low pass device as shown in Fig. 4. The corner frequencies may be programmed entirely separately for each: the skirt profile can be symmetric, asymmetric or whatever.

While discussing programming of filter characteristics it is probably worthwhile to digress to see just what is involved. Returning to the basic low pass equation:

$$E_{out} / E_{in} = \frac{1}{\left(1 + \omega^2\right)^n}$$

It will be recalled that the ω^2 term was produced by a process of double differentiation: if this had been preceded or indeed succeeded by some gain say A_0 then the basic equation would have taken the form of:

$$E_{out} / E_{in} = \frac{1}{\left(1 + A_0\omega^2\right)^n}$$

By changing just one parameter (the gain factor A_0) the break frequency of the filter can be programmed quite arbitrarily and totally independent of anything else. A further important parameter which will need to be varied is of course the order of the filter n. This is where the structured approach has one of its most significant advantages. The order of the low pass filter and indeed the high pass, band pass or any other based upon the same principles is defined simply by the coefficient of the logarithmic terms in numerator and denominator. It will be recalled that multiplication of a logarithm by a number results in that number being raised to that power. Thus to obtain a tenth order filter, one simply multiplies the logarithms involved by 5 since the ω term has been raised to second order by double differentiation. This results in tenth order behaviour in total. If the logarithms had been multiplied by 50 this would have resulted in a filter of order 100. Establishment of filter order is seen to be completely independent of break frequency and without a proportionate number of reactive components. The only reactive components required as might be expected are in the differentiating networks and there are only two of these whatever the order of filter; even for very low frequencies they can be small in value due to the use of the amplification factor A_o which multiplies their effective value.

Silicon Technology Considerations

The techniques of SAE are applicable to bipolar, cmos or bicmos. Over and above an obvious requirement for basic transistors there is a need for voltage to current converters which, in bipolar or bicmos technology, would be provided by linear resistors formed by diffusion or implantation. Although techniques are available to linearise voltage to current sources in cmos, these are not essential. Non-linear devices can be used providing that their characteristics are predictable and consistent: for instance the square law behaviour of a mos transistor in its unsaturated region.

In addition to voltage to current conversion a logarithmic device is also required and this is needed for the logarithmic and anti-logarithmic instructions. In bipolar and bicmos technology this can be provided by a bipolar transistor with its collector connected to base. As mentioned in the first article on structured analogue electronics the consistency of logarithmic behaviour extends beyond eight decades of current range. Whilst PN junctions are not necessarily accessible in basic cmos technology an alternative is to operate the basic transistor in its sub-threshold region where a logarithmic relationship between drain current and gate voltage exists. Highly complex systems would clearly favour cmos for example whilehighest frequency applications would favour straight bipolar or bicmos.

Cells providing the basic instruction repertoire can be designed to perform at 1Hz or 100MHz; it is simply a matter of providing sufficient current to achieve the required performance, particularly in terms of slewing rate for the logarithmic and associated functions.

Cad for SAE

While filters created with SAE techniques are of great interest it should be remembered that the driving force was the desire to take the black art out of designing analogue circuits with computer design tools. Adopting a highly structured approach such as that shown with the low pass filter example means that the application of cad technique is suddenly very much easier.

Current design is very much at the component level and the cad tools available are therefore limited to Spice and its derivatives. SAE switches to a much higher level of abstraction and thus facilitates massive increases in speed. A repertoire of just seven instructions has been proposed with which it is believed that the design of any analogue system can be undertaken. The low pass filter example shown here requires six of the set of seven. In designing other analogue functions from voltage references to radio receivers it is thought that the basic set of seven is sufficient and indeed there is possibly some redundancy but this results in the simplification of hardware. The amplifier instruction is such a case in point. In its basic form the application of cad to the design of SAE is very straightforward. SAE application software is now under development which will run on IBM compatibles and greatly simplifies the design procedure. SAE works at such a high level of abstraction the speed up factor over component level design is staggering. ■

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1 The Art of Electronics. Horowitz and Hill, published by Cambridge University Press pp 263- 284.

2 Interfacing with C. Howard Hutchings. A collected series of articles first published in Electronics World + Wireless World from April 1990 to May 1991. Published by Reed Business Publishing Group

Four op-amp inputs are better than two

Performance of the LT1193 and LT1194 video difference amplifiers prompted Ian Hickman to reconsider bridge circuits.

Back in the 1970s when the RCA *CA3130* bimos op-amp became available, its very high input impedance compared to the existing bipolar types meant it was clearly the answer to an engineer's prayer.

I decided it was just the thing for the detector in a bridge circuit, but there was a snag. A bridge detector needs not only a high differential input impedance, but also both inputs must present a high impedance to ground, to simulate the conventional floating detector circuit.

With gain defining resistors fitted this is no longer the case. But the amplifier cannot be used without them since the open-loop-gain times the offset-voltage could result in the output being driven to one of the rails. Of course a high impedance for both inputs could be supplied with the usual instrumentation amplifier set-up of **Fig. 1a**. But why use three op-amps if you can get away with less?

Circuit **Fig. 1b** uses only two. But I was unaware of that particular arrangement at the time and in my circuit (**Fig. 2**) an NFB loop around the amplifier is closed via one of the offset null terminals, leaving both the –ve and +ve (inverting and non-inverting) input terminals free to float.

With the offset null trimmed out, the circuit made a fine detector for a DC excited resistance bridge – the *CA3130*'s 90dB typical CMRR (common mode rejection ratio) resulting in negligible error with change in bridge ratios.

But the circuit also made a fine inductance bridge, the values in Fig. 2 giving a $100\mu H$ full scale range. R_s was switchable to $1k\Omega$ or $10k\Omega$ giving 1 and 10mH ranges, and then switching C_s to 100nF gave 0.1, 1 and 10H ranges.

The op-amp's input stage is outside the NFB loop, so its gain will vary somewhat with temperature. But for a bridge detector that is not important. In any case a wide range of gain control was needed to cope with the different bridge ratios and this was supplied by the 100K log sensitivity pot.

CMRR of the *CA3130* at 1592Hz (ω = 10^4rad/s) is not stated in the data but seemed adequate for the purpose, and the resultant simple RCL bridge served me well for many years.

Video differences

Recently the *LT1193* and *LT1194* video difference amplifiers came onto the market[1], available in the UK from manufacturer Linear Technology Corporation.

They are part of the *LT119x* family of low-cost high-speed fast-settling op-amps, which

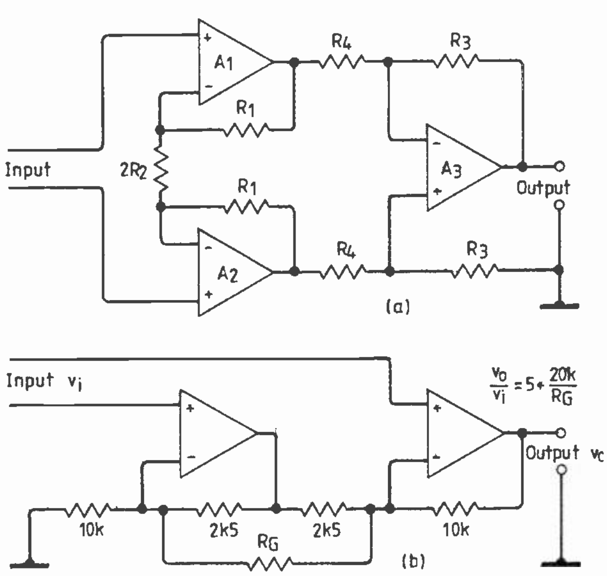
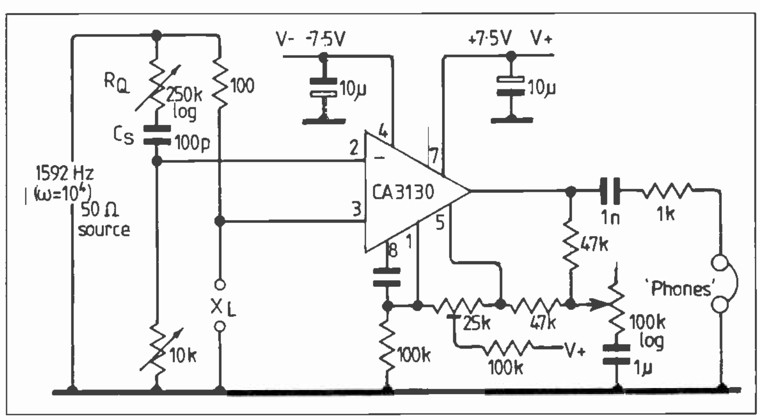


Fig. 1. Instrumentation amplifiers, floating high-impedance input. Circuits using (a) three op-amps or (b) two op amps.

Fig. 2. Inductance bridge with a 50Ω source providing a DC path to ground.



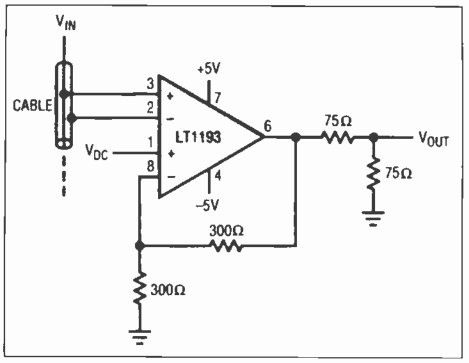


Fig. 3a. Cable sense amplifier for loop through connections with DC adjust.

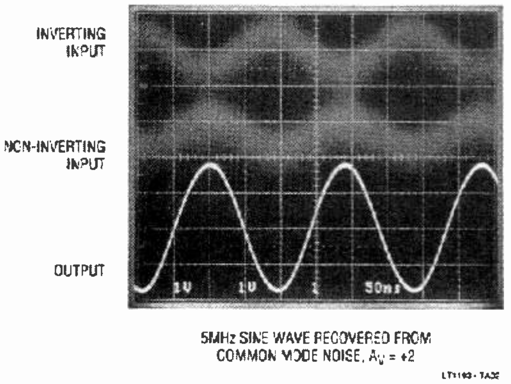


Fig. 3b. Recovered signal from common mode noise.

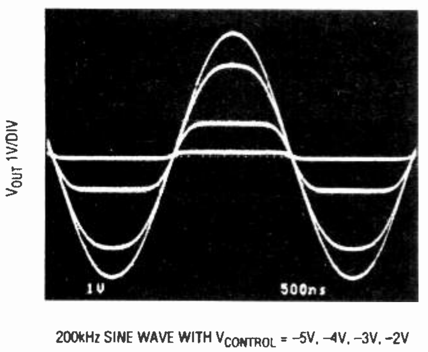


Fig. 3d. Sine wave reduced by limiting the LT1194.

includes devices with gain-bandwidth products up to 350MHz. All have a 450V/µs slew rate and with this sort of performance, you won't be surprised to learn that the parts use bipolar technology.

The *LT1193* and *LT1194* video difference amplifiers differ from other members of the family in that they have two pairs of differential input terminals, so that the gain-defining NFB loop can be closed around one pair, leaving the other pair floating free. Input impedance of the *LT1193* is typically 100K in parallel with 2pF at either the –ve or the +ve input. **Figure 3a** shows the device used as an 80MHz (-3dB) bridging-amplifier, tapped across a 75Ω coaxial video distribution system.

The arrangement is clearly much more economical than the usual termination of the incoming signal in a video repeater amplifier housed in a distribution box. It also provides a fan-out of several outputs, for local use and for the continuing run to the next distribution box.

The signal in the cable is nominally unbalanced (ie ground referenced), but in practice there are ground loops between pieces of equipment, and high frequency common mode noise is often induced in the cable. So the bridging amplifier at each tap location requires a high CMRR at high frequency. **Figure 3b** shows a 5MHz signal recovered from an input with severe common mode noise, illustrating that the CMRR is maintained at high frequencies.

My floating input *CA3130* circuit's gain was not well defined, the input stage being outside the gain defining NFB loop, but the LT1193 does not suffer from this disadvantage. Its two input stages are provided with identical emitter to emitter degeneration resistors, **Fig. 3c**, so that the gain at the –ve and +ve inputs (pins 2 and 3) is the same as that defined at the reference and feedback inputs, pins 1 and 8.

Gain error is typically 0.1% while the differential gain and phase errors at 3.58MHz are 0.2% and 0.08° pk-pk respectively. While excellent as double-terminated 75Ω cable drivers, the *LT1193/4* are capable of stably driving 30pF or more of load capacitance with minimal ringing.

Unique power conserve

The *LT1193* features a unique facility, accessed by pin five, that enables the amplifier to be shut-down to conserve power, or to multiplex several amplifiers onto a single cable.

Pin 5 is left open circuit for normal operation, but pulling it to the negative supply rail gates the output off within 200ns leaving the output tri-stated and typically reducing the dissipation from 350mW (with +5V and -5V rails) to 15mW. The *LT1194* – gain internally set at x10 – has a different party trick, made possible by bringing out the emitters of the input stage's constant current tail transistors. The design enables the input stage's current to be reduced by degrees, limiting the available output swing, **Fig. 3d**, extremely quickly.

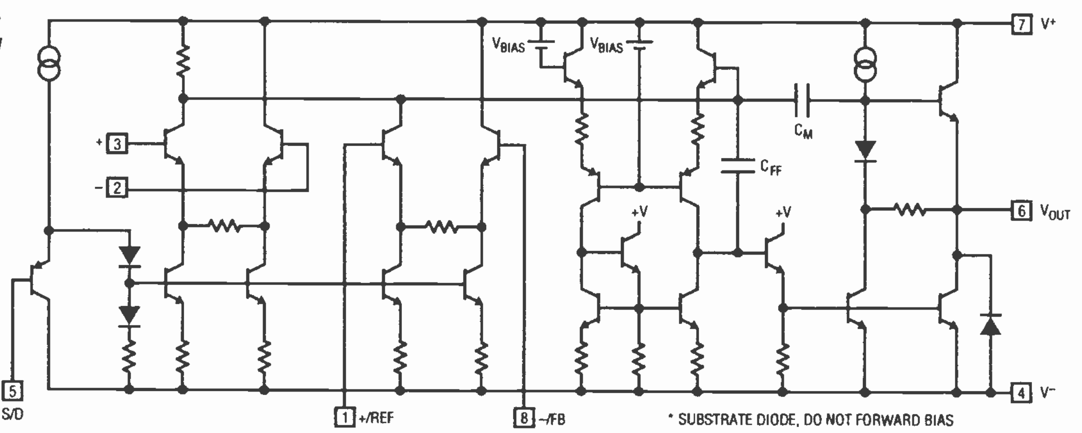
Bridge application

Application of the fully floating input stage of the *LT1193* to my old bridge circuits seemed an obvious move, and with the device's CMRR still in excess of 55dB at 1.592MHz, **Fig. 4a**, the bridge could clearly be run at $\omega = 10^7$, enabling much lower values of inductance to be measured. The result was a hasty building and testing of a new circuit (**Fig. 4b**).

With the values shown, inductances up to 200nH can be measured. The circuit was tried out using a "Coilcraft"[2] five and a half turn air-cored inductor of 154nH, type 144-05J12 (less slug). I have not yet succeeded in finding a non-inductive 20Ω potentiometer for R_V, so balance was achieved by selecting resistors on a trial and error basis. The bridge balanced with R_V equal to 15Ω in parallel with 220Ω, and with a 180pF capacitor as the tan delta "control". These values give the inductance as 145nH and the Q as 5.5.

Measured value of inductance is a little adrift, but that is not surprising, given the bird's nest construction. Indeed, a quick check by connecting both inputs to the same side of the bridge showed that I was only getting 47dB CMRR – after removing the 100nF capacitor decoupling the negative rail which

Fig. 3c. LT1193 simplified schematic.



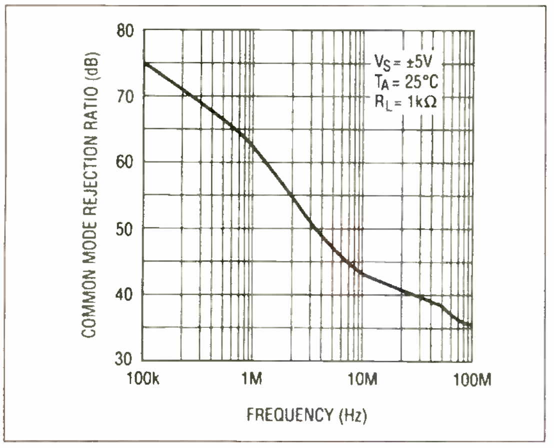


Fig. 4a. Common mode rejection ratio vs frequency for the LT1193.

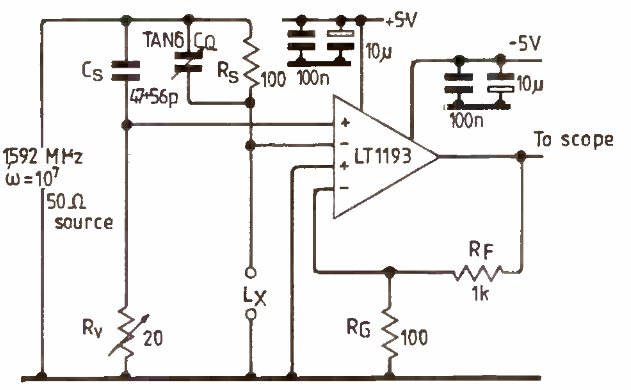


Fig. 4b. The "hastily constructed" circuit using the LT1193 in a bridge application

should have made things worse, not better. But perhaps such oddities should be expected by anyone rash enough to use experimenter's plug board construction.

Manufacturer figure for Q is 154 minimum at 40MHz. If we assume that Q is proportional to frequency, the "measured" Q is 138. But the manufacturer's figure of 154 is with the slug fitted, at mid range, giving an inductance of 207nH. At 154nH, without the slug, a lower value of Q is only to be expected. In fact, results from the bird's-nest test bed are so encouraging that the circuit will probably now be rebuilt – properly!

References:

1. "Linear Technology", Vol 1, No 2, October 1991.
2. Coilcraft, 1102 Silver Lake Rd., Cary, IL 60013 USA (312) 639-6400. Also in the UK at 21 Napier Place, Wardpark North, Cumbernauld, Glasgow G68 0LL.

PUTTING MIC AMPLIFIERS ON THE LINE

High-quality low-noise microphone signal amplifiers must cope with a wide range of demands. Tim McCormick discusses suitable devices and circuit topologies, and describes a practical circuit.

Microphone amplifiers must be capable of dealing with a great variety of situations, but when looking at design it perhaps makes sense to consider the worst possible case first. Lowest outputs of all microphones are experienced with the ribbon mic and, as a result, these demand not only considerable amplification but also excellent common mode rejection (CMR) so that outside interference picked up by microphone lines is efficiently rejected.

In a typical classical recording session, a ribbon mic will deliver about 1mV down a balanced line of perhaps 50m in length, from a source impedance of 200Ω. So units designed to amplify the signal up to line level without adding significant noise should comfortably be able to handle higher output mics and closer working distances through variable gain. This allows optimising of output levels and overload margins.

Sources of noise

Noise in a dynamic microphone comes from thermal excitation of the charge carriers in the resistive elements – the coil, ribbon, transformer and windings.

A standard 200Ω output impedance is low enough for up to 100m of screened (ie capacitive) cable to be driven without loss of signal below 20,000Hz. At the same time the level is high enough to allow the microphone designer to use sufficient windings on the voice coil and/or a sufficient step-up ratio in the microphone transformer to achieve a useful voltage output.

The absolute noise level emerging from a 200Ω source is about 256nV at room temperature in a 20kHz bandwidth. A microphone's "equivalent self noise" relates voltage output level to absolute noise level, for a standard SPL of 94dB – a decent-quality ribbon mic like the Beyer *M130* gives 1mV from a 200Ω source in a 94dB sound field.

Its signal to noise ratio is therefore 20log(1mV/0.000256mV)≈72dB and its equivalent self noise level is obtained by subtracting this from 94, giving a figure 22dB. That means that in complete silence the mic will deliver a noise output equivalent to what it would produce if 22dB of sound were present.

But this is not quite the whole story. A level of 22dB is very quiet indeed, a quiet living room being around 35dB or so. Unfortunately microphone (and electronic) noise tends to be "hissy", and so is more noticeable than the simple dB level suggests.

Capacitor microphones have considerably larger absolute noise outputs than ribbons. But output levels are correspondingly higher; so resulting S/N ratio tends to be around 76dB or better with an equivalent self noise being around 18dB, A-weighted.

A-weighting the above-quoted 22dB for the *M130* improves it by a couple of dB, but very low noise microphone amplifiers are mandatory for the ribbon if noise level is not to become unacceptable.

Microphone self noise values in the low twenties are on the borderline of acceptability for recording speech and the quieter types of classical music. So the equivalent input noise of a microphone amplifier needs to be as low as possible (input noise = output noise + gain).

For example, output noise from a "noiseless" amplifier would simply be that due to the amplified source noise. The standard source resistance is 200Ω and output noise is related to the standard line level of 0dBu = 775mV, to give the dB ratio.

The equivalent input noise of a noiseless amplifier terminated with a 200Ω source is –129.6dBu, obtained by expressing the 775mV line level, and the 256nV noise level of the source, as a dB ratio: 20log(775mV/0.000256mV)≈129.6dB. If the amplifier has a gain of 60dB, then its output signal to noise ratio is 129.6 – 60 = 69.6dB, about the same as a cassette deck with Dolby C, or good FM stereo.

Good professional microphone amplifiers achieve –128dBu, the theoretical maximum being –129.6dBu.

But care is needed when comparing specs: three factors in particular must be borne in mind: 20kHz bandwidth unweighted (watch for smaller bandwidths and weighting flattering the figure); 200Ω source (some companies now quote for a 150Ω source which is quieter); and a reference level of 0dBu = 775mV (some quote for 0dBV = 1000mV, which again flatters the result).

Choosing components

One or two manufacturers are using the Analogue Devices *AD845* IC as a microphone amplifier, capable of a genuine −129dBu equivalent input noise – given the right circuit design. But a discrete design does have the advantage of freedom of choice in parameters such as maximum available gain without compromising noise.

We need to choose a transistor with the lowest possible noise bearing in mind that the principal noise generator is the base spreading resistance, $r_{b'-b}$. This is a "real" resistance which exists between the base lead of the transistor and the actual base inside the transistor itself. As a noise source, it appears in series with the microphone or other device feeding it producing, in effect, a higher source impedance and therefore higher noise.

Occasionally you can persuade semiconductor manufacturers to admit that $r_{b'-b}$ exists, but I've never been able to extract actual values. (**Table 1** gives a list, obtained by measuring at least five samples of each in a test circuit).

The trend is that PNPs have a consistently lower $r_{b'-b}$ – the "low noise audio" *BC109* is in fact one of the noisiest.

BC461 was designed as a high-voltage driver transistor in a T039 package, but turns out to be just what is required if its relatively low input impedance due to its low h_{FE} (and high collector current) can be handled.

Professional 200Ω microphones like to work into an impedance of around 1kΩ or greater, so the *BC461* is suitable and there are no messy parallel arrays to worry about in achieving low noise. A pair of *BC461s* in a differential configuration adds 40Ω to the 200Ω source resistance, indicating that an equivalent input noise of −129dBu is possible, only 0.6dB noisier than theoretical perfection.

For a given source resistance, if the transistor is to deliver minimum noise, there is an optimum collector current: $I_C = \sqrt{h_{FE}}/40R_S$. The relationship tends to break down when I_c's of greater than about 1mA for the *BC461* are used. The value of 0.84mA was found to be suitable for the circuit design while not compromising noise performance.

Circuit topology

Having chosen the transistors and their operating points, the circuit topology must be considered. The long tailed pair is popular for differential or "balanced" signals (**Fig. 1**) and is the basis of the instrumentation IC. The constant current source feeding the transistor emitters sets collector currents and improves common mode rejection since one transistor can only conduct more current if the other transistor conducts correspondingly less current. Simultaneously altering the current flowing through both requires that the current flowing through the constant current source must also change. By definition, the latter will not allow this so the two transistors are prevented from responding to an exactly-similar input signal and CMR is excellent.

Careful matching of the pair is essential, as is a carefully optimised current source, and though IC fabrication achieves this comfortably, in a discrete design it is not so easy. A particular transistor likes to settle in to its own value of collector current, the value depending on its exact base-emitter quiescent voltage and design of the circuit. Thermal tracking between two discrete transistors is poor unless both are matched and thermally coupled in some way. A constant current source tends to impose itself on the transistors, so after developing and using such circuits for a time I decided to abandon the technique, fearing that the transistors were not finding their true operating points despite careful matching.

CMR without the current source proved to be fine – providing that transistors were carefully matched and that the impedance of each input leg could be adjusted and made exactly equal.

Figure 2 shows the basic input topology. Tr_1 and Tr_2 are the input long tailed pair.

Assume gain is set to maximum, and R_3 and R_4 are in effect a parallel pair, shared by both transistors. Tr_3 and Tr_4 act as DC servos for Tr_1 and Tr_2 respectively, but do not appear in the audio path. C_1 and C_2 prevent any AC feedback.

In every discrete balanced microphone amplifier that I have seen the long-tailed-pair works directly into a differential IC or similar arrangement, and their emitters can not be directly coupled, **Fig. 3**. But remove C_1 and replace it with a wire link and each transistor now shares the same resistor path to $+V_{cc}$. Proper DC biasing will not be set up due to the inevitable differences in thermal conditions between Tr_1 and Tr_2. Each transistor needs to find its own operating point. Even a constant current source can not guarantee equal current through both devices in a discrete design and we have thermal instability.

C_1, a large-value electrolytic capacitor, is inserted to prevent this. It has no DC bias across it, is arbitrarily oriented, and is in the local feedback path.

Furthermore, at full gain its high impedance at low frequencies causes feedback, and attenuation of the low frequencies. The way round the attenuation is usually to insert a resistor of

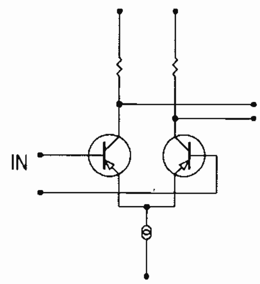


Fig. 1. The long tailed pair is popular for differential or "balanced" signals.

Table 1. List of various $r_{b'-b}$, obtained by measuring at least five samples of each in a test circuit.

NPN	rb'-b	PNP
BC108	300	
BC104, BC168	250	
	170	BC213L
BC107	150	
BC547	140	
	100	BCY71, BC557, BC179
	85	BC212L, BC213B
	70	BCY70
	65	2N4403
BD131	40	2N4402
BD139, BC441	30	BD140
	20	BC461, BC143

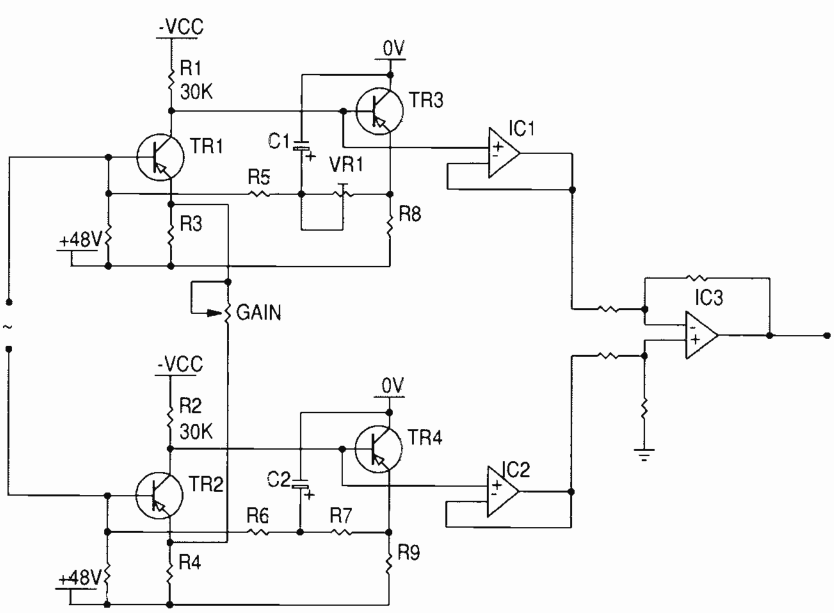


Fig. 2. Basic input topology. Tr_1 and Tr_2 are the input long tailed pair and R_3 and R_4 are in effect a parallel pair, shared by both transistors. Tr_3 and Tr_4 act as DC servos for Tr_1 and Tr_2 respectively. C_1 and C_2 prevent any AC feedback.

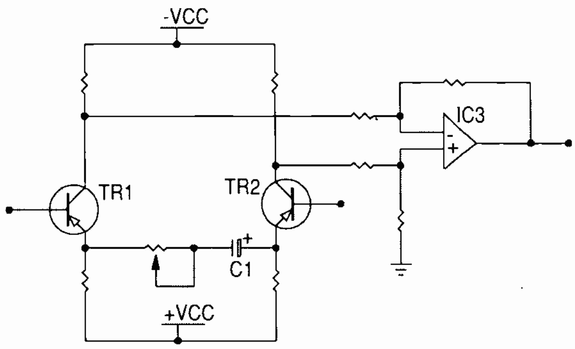


Fig. 3. In discrete balanced microphone amplifiers the long-tailed-pair works directly into a differential IC or similar arrangement, and emitters cannot be directly coupled. Remove C_1 and replace it with a wire link and each transistor now shares the same resistor path to +Vcc.

around 47Ω or more in series with the capacitor to swamp its LF impedance. But this generates noise and compromises performance. The effect on sound quality of this uncharged large-value capacitor can be demonstrated by inserting one in series with the gain-control in the final design: clarity of the circuit is reduced. Tr_3 and Tr_4 in Fig. 2 provide independent biasing for the long-tailed pair, and a capacitor is not necessary.

When gain is at maximum the combined noise from R_3 and R_4 is amplified equally by Tr_1 and Tr_2, and so cancels out at IC_3's differential input. As a result there is no "emitter degradation" noise, and the only significant noise is from the 200Ω source itself, plus a little from Tr_1 and Tr_2. These are set to give almost all of the gain in the circuit, so the signal level is high at the collectors and noise from R_1, R_2 and the ICs is rendered insignificant.

The gain of Tr_1 and Tr_2 is given by $40R_LI_C = 40 \times 30k \times (0.84 \times 10^{-3}) = 1008$ though in practice it is a little lower.

Reducing the gain by adding resistance between the emitters of Tr_1 and Tr_2, gives local feedback and *is* a source of noise, because its thermal noise output appears in mutually opposite phase to the two transistors, so is summed, not cancelled, at IC_3.

Practical design

In the practical design, putting a 240Ω resistor here – giving 3dB of noise degradation of a 200Ω source plus input transistors – brings about a 12dB reduction in gain. Output noise falls much more rapidly through gain reduction than it rises due to emitter degradation. At high gain settings, where noise would cause most problems, emitter degradation is minimum.

Complete lack of negative feedback at full gain means the circuit gives relatively high distortion, but it is almost purely second harmonic, and subjectively innocuous. At the full 60dB gain setting, and with a 2mV input giving 2V of output, distortion is about 0.08% across the audio band, reducing to 0.015% below the 50dB gain setting.

Subjectively assessing the circuit at full gain with a 60dB attenuator placed at the input with the whole unit in a tape loop, I found it difficult to tell when it was in circuit and when it was not.

For a stereo unit, all four input transistors need to be carefully matched, as do all four servo transistors. **Figure 4** shows a test circuit for the *BC461* and **Fig. 5** for the *2N4402*. Measurements of I_B produced four matching specimens of each from samples of about thirty of each. I_B of the *BC461*s was 6.8μA, with 3.8μA for the *2N4402*. The latter could be replaced by alternatives such as *BCY71*, *BC179* etc.

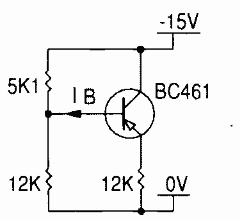


Fig. 4. Test circuit for the BC461

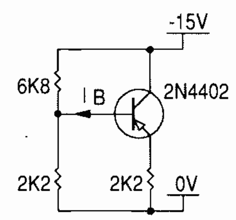


Fig. 5. Test circuit for the 2N4402.

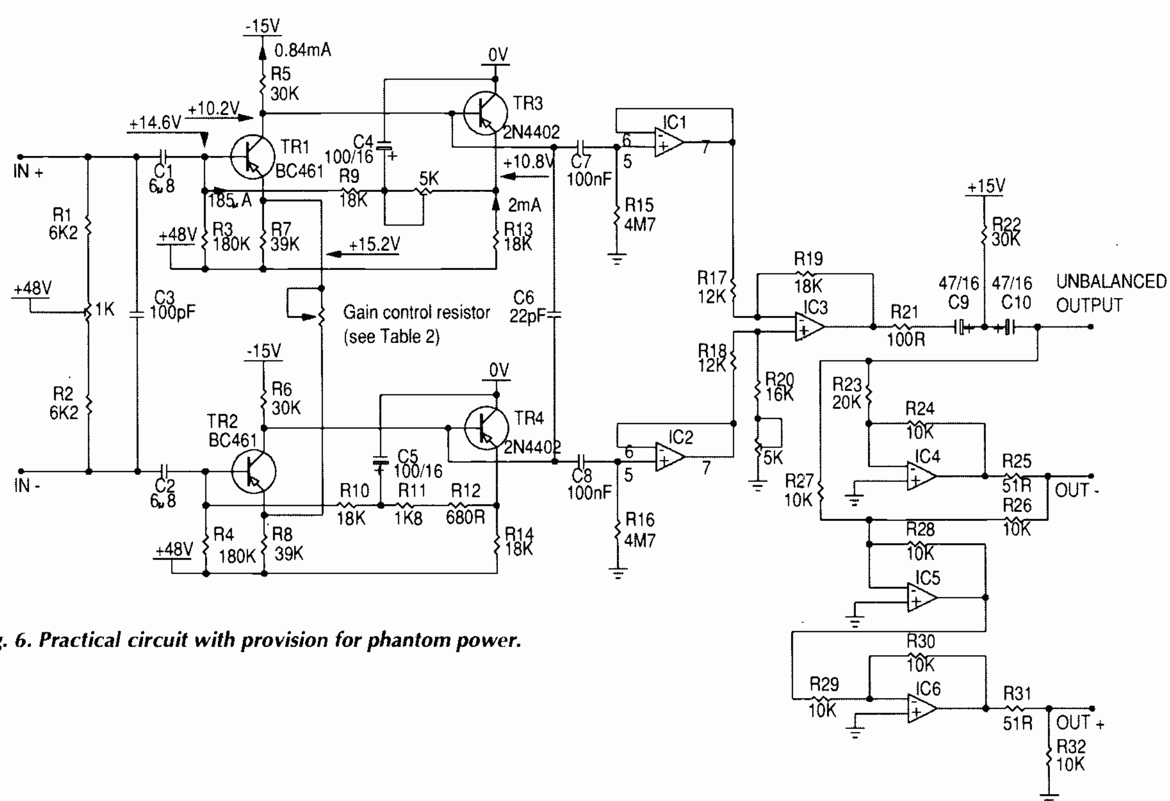


Fig. 6. Practical circuit with provision for phantom power.

Table 2. Wafer resistor values to achieve gain steps of 2dB across a 40dB range.

Target gain dB	Measured gain L	Measured gain R	added resistance
60	60.98	60.98	0
58	59.04	59.1	20
56	57.04	57.1	27
54	55.1	55.16	33
52	53.0	53.03	47
50	51.0	51.04	56
48	49.1	49.16	68
46	47.2	47.3	82
44	45.1	45.2	120
42	43.05	43.2	150
40	41.1	41.26	180
38	39.3	39.4	220
36	37.1	37.24	330
34	35.16	35.3	390
32	33.2	33.4	470
30	31.15	31.3	680
28	29.2	29.36	820
26	27.3	27.5	1k
24	25.2	25.4	1k5
22	22.98	23.18	2k2
20	20.96	21.18	2k7

The practical circuit, **Fig. 6**, has provision for phantom power. The 5k preset leading from the emitter of Tr_3 is trimmed, with the gain wafer disconnected, to give zero voltage gradient across the emitters of $Tr1$ and Tr_2, matching their operating points. 1k preset trims input impedances to sharpen up CMRR in conjunction with the 5k preset at IC_3.

Good common mode rejection is most needed at high audio frequencies and maximum gain, so a 10kHz signal of about 500mV is applied to both input legs in phase, with a full gain setting. The two presets are adjusted to give negligible output, and greater than 80dB CMR can easily be achieved.

Some capacitor mics (for example some AKGs) draw a lot of current, producing large voltage drops across R_1/R_2. C_1 and C_2 can then be reverse-polarised, so need to be non-polar. C_5 and C_6 give protection against RF interference. The idea behind using IC_1 and IC_2 is to provide a very light load for the collectors of Tr_1 and Tr_2. Also, the impedances of the +ve and –ve inputs of IC_3 are different in nature, and are best fed by IC_1 and IC_2 rather than the transistors.

DC offset at the unbalanced output is dealt with by C_9 and C_{10}, correctly DC biased by R_{22}. The balanced output circuit is configured so that grounding the –ve output to feed an unbalanced input automatically causes the voltage of the +ve output to double, preserving full output voltage.

IC_1 and IC_2 are *TL072s*, offering very high input impedances and having an easy load to drive. ICs 3, 4, 5 and 6 are dual *NE5532s* which are unity gain stable and can deliver +20dBu into 600Ω. The resistors at the outputs of the ICs protect them from instability when driving capacitive loads.

Table 2 gives wafer resistor values to achieve gain steps of 2dB across a 40dB range. Measured values for both channels are given, together with each successive resistor value along the wafer. The total resistance at the 20dB setting is just over 11k. A 10k reverse log pot is too inaccurate for good channel matching and fine control.

Impressive gain match between channels throughout the whole 40dB range was achieved using matched transistors as described, 1% resistors throughout, and no further tweaking. The large +48V rail endows the circuit with impressive overload margins, and permits very large R_7/R_8 values for to allow a 40dB gain range without resorting to global feedback ■

Comparing sensitivities

Microphones are low output devices; in the recording of classical music signals from them can be expected to be in the millivolt range.

Mic sensitivity is often specified in mV/μB. One μB (microbar) is equivalent to 74dB SPL, and fairly loud speech at a distance of one metre gives a good idea of what this level means in practice. Capacitor microphones deliver around 1mV of output for this SPL, and so an electrical gain of x775 or ≈58dB will be required from a microphone amplifier to raise the signal up to the standard 0dBu "line" level of 775mV.

Moving coil and ribbon microphones give output levels as much as 20dB lower, so correspondingly greater amplification is needed.

REGULARS

LETTERS

Distorted truth

Malcolm Hawksford seems to have lost the plot with his comments (Letters, *EW + WW*, March 91) regarding my artide "Distorting power supplies' (*EW + WW*, December 90). Having since obtained copies of his refs 1 and 9 (ref 2 proving more elusive) I acknowledge that Prof Cherry's article also begins with an identification of the half wave rectified supply currents, and their harmonic analysis – which can be found in any elementary text on Fourier analysis – my only reference for the article.

From this fundamental point on, our directions diverge. My aim was to expose the emphasis on the generated harmonics arising from inductive supply impedance. Also, upon injection into the amplifier proper through its declining, at typically 6dB/octave, high frequency PSRR, significant levels of generated harmonics can result in response to a pure tone sinewave input. This can act to mask the spatial and timbral detail in a complex audio design.

Far from being "Distorted History," this (along with poor layout and lead stress induced proximity interactions) is probably THE most important mechanism responsible for the anomalous behaviour of many "audiophile" class AB power amplifiers. The approach has led to absurd over-building of power supplies, continued use of class A – despite the ready availability of high speed devices such as mosfets – and use of fully regulated power suppliers at great size, weight and cost penalty.

Flick through the pages of any of the "authoritative" audio publications to witness a "golden eared" reviewer drooling over some vastly over-built power supply as though it were a design attribute rather than the naive, resource-wasteful band-aid that it is. Commercial examples abound of power amplifiers designed with little or no regard for PSRR, being operated with massively over-built power supplies and/or a high level of class A operation to retrieve some sonic virtues. Invariably such ampifiers sound "hard" once the class A to class B threshold is exceeded as the fundamental problem re-emerges – poor design. Such amplifiers also miss out on the advantages of dynamic head-room present in designs with "soft" supplies which better provide for the dynamic/transient demands of music.

The trend towards DC-coupled power amplifiers has exacerbated the problem as the servo chips used are often poorly decoupled derivatives of the main supplies and have rather poor and wide tolerance PSRR as they have more likely been selected on input impedance criteria so that a long RC time constant can be achieved. Their output is usually fed directly to the amplifier input through an appropriate resistor rather than subjected to any level of output filtering.

Virtually all audio IC op amps operate a class AB output stage and tests performed on 14 popular types showed THD on the supplies of between 2% (*AD845*) and around 40% (*LF356*, *OP77*, *LT1057*) at only 1mA output. Some of the most popular chips, often used as D-to-A interface and filter chips are not even specified for PSRR vs *f*, so it is not difficult to see why budget CD has such a "detached" sound, and supply improvements and premium chips are a popular and effective tweak.

Malcolm Hawksford's suggestion that any power supply induced distortion appears/disappears as a common mode signal on the outputs of a bridged amplifier sharing a common supply is certainly true – in theory.

However I doubt he is recommending the doubled complexity, and cost, as a commercially viable fix.

In practice, every commercially available bridgeable amplifier I have auditioned has a noticeably "heavier" and "darker" sound, lacking in detail in comparison with its normal operation in single ended stereo mode. This can be attributed to the fact that most are configured as in Fig. 6 of my original article.

Both channels do not share all the inductive components of supply wiring as a result of the need for physical separation for best performance in stereo mode. The heavier loading of (say) 8Ω bridging, acts to double supply currents and exacerbate output stage distortions - the main source of distortion in most power amplifiers. This is particularly so under the low impedance and reactive loading of many modern esoteric loud-speakers.

Finally, comparison of high feedback vs low feedback was considered beyond the scope of the article. But I might add that the use of global (and nested) feedback is a useful tool for suppressing injection following the input stage. It should not be discounted when compared with the complexities necessary to isolate each and every stage of a low feedback multi-stage design, and is very effective in addressing output stage nonlinearity.

The analysis, in the appendix of Malcolm Hawksford's own ref 3, was unable to establish a case for low feedback, except to suggest that as R_g tends to infinity, the distortion is processed completely by the feedback loop .

While I would never suggest that such injected distortion be permitted to dominate the open loop non-linearity of the amplifier, the argument is flawed and I suggest Malcolm Hawksford considers the situation where R_g is instead a capacitor and the dominant pole of the nested loop in a high feedback

ALL our own idea

In February's EDN Design Spotlight (*EW + WW*, Feb. 1992), Ian Hickman expresses surprise at the idea of an amplitude-locked loop (ALL). In fact to our knowledge, the idea was first conceived by AM Pettigrew and further developed by AM Pettigrew and TJ Moir in 1989. The diagram shows a simplified ALL consisting of a linear multiplier, precision modulus detector and integrator. (Note the difference between this circuit and the one published in the feature).

The ALL is a high bandwidth servo system and is the perfect dual of the phase-locked loop (PLL). In place of the VCO in a PLL is the linear multiplier and in place of the phase detector is the modulus detector.

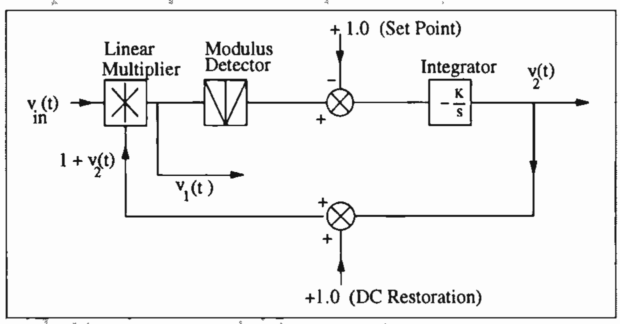
For a carrier based signal $V_{in}(t)$ at the multiplier input with amplitude variations, two outputs are generated by the ALL. The signal $V_1(t)$ is the recovered carrier with amplitude variation removed.

Signal $1+V_2(t)$ is the reciprocal of the envelope of $V_{in}(t)$. The circuit has numerous applications when used in association with other circuitry. In particular the theory and application of a noise cancellation system for FM transmission has been developed[1]. The noise cancellation system gives up to 6dB in threshold extension at low carrier to noise ratios.

Other applications include the application to DSSC and AM demodulation. Patents were filed in January 1990[2]

T J Moir and A M Pettigrew
Renfrewshire

1. AM Pettigrew and TJ Moir. "Reduction of the FM threshold effect by inband noise cancelling". *Electronics Letters*, 6th June 1991, Vol 27, No 12, pp.1082-1084.
2. Amplitude Locked Loop Circuits, British patent application No. PCT91/00101, Ampsys Ltd.



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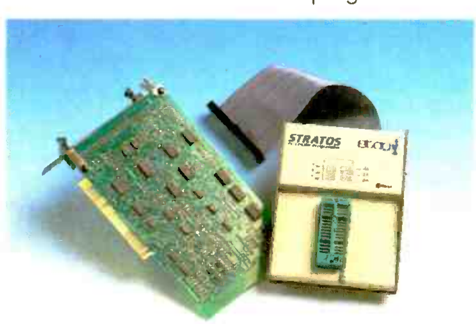

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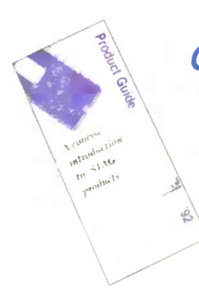

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Greg Ball
Coolangatta
Australia

Disabled system design

Your Comment on ergonomics of design – or rather the lack of it ("For humans... by design," February) was of particular interest to me, as harmonising electronic systems really matters in my field of aids for disabled people.

My interest in this field was sparked off by seeing, some years ago, a Possum communicator in use in a special school for spastic childen. It was so clumsy and ineffective that I became angry, and resolved to do something better.

Now older and wiser, I realise that the sociology of such aids is important. An aid that is really useful for a spastic child may seem troublesome and expensive to carers. Designs must be aimed at a particular client group and at a particular set of interests. But the trouble is that, in general, it is the *carers* of disabled people who buy equipment. Any new aid also has to find its niche in the market for aids already in use by disabled people – who may themselves have a fear of new technology.

In fact new technology is not universally welcome, and I feel that too many manufacturers in my field are interested in gimmicks rather than addressing the real problems.

Alan Campbell
Newcastle

I am a Zambian and a holder of a certificate in information technology and programming, and wish to pursue further studies in computing at Buckingham University, beginning January 1993. I have been offered a place on the two year degree programme in computer science with business studies but cannot bear the costs myself.

Efforts to secure financial aid from local and international agencies have all been to no avail, and no university offers computer science here.

Can the readers of *EW + WW* help me find a way to continue my studies?

Jerome Ghabuka Kawesha
PO Box 71596
Ndola
Zambia

A mathematician challenges

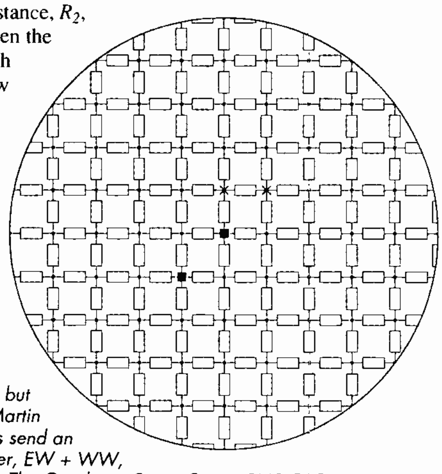
EW + WW readers may be interested in this resistor puzzle, which I discovered during a study of cyclic resistor networks – at the very least, the puzzle demonstrates what an engineer working in mathematics makes of resistors.

On my desktop stands an arrangement of approximately 1000 resistors, assembled in a diamond lattice. In the infinite resistor network shown, all resistors are equal and have value R. Try to answer the following questions:

Question 1: What resistance, R_1, do you measure between the two points marked with an x and how do you ustify your answer. (The question is easy to answer and no mathematics is needed.)

Question 2: What resistance, R_2, do you measure between the two points marked with a black square and how do you justify your answer (A harder question to answer and you will probably need some mathematics.)

Martin Ohsmann
Lehrstuhl I f. Mathematik
Germany



No prizes for guessing, but if you want a copy of Martin Ohsmann's full solutions send an SAE to: Lorraine Spindler, EW + WW, L333, Quadrant House, The Quadrant, Sutton Surrey SM2 5AS.

Class struggle

Unlike the classification system for blood groups, the A/AB/B label applied to amplifier topologies would appear to have outlived its usefulness, judging from the regular trickle of letters on this point. Different push-pull topologies running with non-zero standing currents behave differently on being called to deliver load current – as any seasoned amplifier designer will have discovered.

To use a single classification which ignores the internal transfer function of the amplifier, let alone the relationship between the static current and the load resistance (if the load is even resistive) leads to the perpetuation of much of the misleading "wisdom" abounding in the popular audio press.

If we agree that class A amplifiers are those where the load current is insignificant, and class B amplifiers are those where the standing current is insignificant, then presumably class AB encompasses the rest.

I would hazard a guess that nearly every sensible commercial amplifier falls into this last category, considering the typical current dynamic range requirement in a modern audio system.

Proliferation of "non-switching" techniques – of which the work by Blomley was an early and valuable example – only serves to make the labelling problem harder.

The generalised non-switching amplifier has an "idle side" behaviour with current flowing in the half of the output stage not delivering current into the load. This has a functional relationship with the load current, and output voltage if desired, which can be controlled by the designer. Countless variations are possible, allowing considerable control over such parameters as variation of device bandwidth, total dissipation, and output stage linearity as a function of load conditions.

I have never built an amplifier to Blomley's designs, but my own research into non-switching techniques has produced production amplifiers with highly satisfactory open loop linearity figures and no trace of typical class change transfer function slope anomalies – all with quiescent currents considered routine by modern mosfet standards. The work has never been published because in my youth I felt that there might be some money to be made from it!

I have no doubt that most designers from time to time come up with a circuit design which they consider patentable. But *EW + WW*'s correspondence files must be littered with letters squabbling about who invented what first.

Doug Self is undoubtedly correct when he observes that the patenting of the Blomley circuit effectively killed it off. Not an evolutionarily successful strategy, then!

Kendall Castor-Perry
Beckenham
Kent

Digital disk alternative

In your Comment on interactive video (Learning from the future, March 1992) you refer throughout to CD-I. But this is just one manufacturer's product. Everything you say – including the comments on current software – applies equally to CDTV, and there will surely be other interactive disk formats from other companies, such as Apple.

There is no reason why interactive software should be confined to optical disks. It is only a software data structure and you could prepare a very neat interactive lecture on organic chemistry (for example) on a 20Mbyte magnetic floppy disk, such as are now available. The mastering costs would be much lower, and a college lecturer could prepare the material with any of dozens of available authoring programs on his or her own hard disk.

I do not own shares in Commodore, nor do I own a CDTV. But I am puzzled as to how you have seemingly been brainwashed by Philips into thinking that their unavailable product is the only one on the market.

Even the normally accurate Barry Fox (Shooting hots up in the video wars, pp. 201-204) has forgotten that digital video disks have been on sale for nearly a year now in CDTV format.

Don Cox
Don Cox Computer Productions
Cleveland

Early radar love

Thank you for the delightful "Birthday challenge" (December 1991 EW + WW, p.1021). I realise I am too late to enter the contest but I have published on this subject before: in the November 1989 issue of *The Old Timers Bulletin* of the (US) Antique Wireless Association, as well as editing an early radar newsletter from time to time, called *RadarHist*.

I would like to extend thanks to you and Rod Burman of Pascall for conceiving and executing this slice of electronic history.

I would also like to correspond with anyone interested in early radar.

Don Helgeson
RadarHist News Letter
9200 Bennet
Evanston
Illinois 60203
USA

■

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Car electronics with Super E-line

E-line and Super E-line transistors from Zetex are designed to handle higher temperatures at higher power dissipations than similar types in *TO92*, *TO237* and *TO220* metal housings, even when the latter are provided with heat sinks. The Zetex devices are in silicone plastic, coping well with the 85°C interior and up to 120°C under-bonnet temperatures in a car. Junction temperatures up to 200°C are allowed.

In Application Note AN78, Zetex describes the trials and tribulations encountered by the average transistor earning its living in the hostile surroundings of a car. Reversed-battery connection, transients caused by load dumps and battery disconnection up to 500V or lower voltages at up to 50joule, mistreatment during maintenance and short-circuits caused by cleaning connectors with a screwdriver are all part of the torture.

Figure 1 shows two ways of protecting a lamp-driver against a reversed battery. With no protection, current would flow through the collector/base junction and into the control IC, leaving devastation in its path. The diode in series with the supply is one solution which works well at the expense of a perhaps inconvenient 0.7V diode drop. To avoid this, the diode across the transistor shorts fault current to ground with no drop, but may possibly interfere with transient protection.

Several types of transient can appear in a car, needing different countermeasures. To overcome the 80V load-dump transient, caused by battery disconnection while the alternator is charging, one can either use a transistor that will handle the 80V or use a clamp; **Figure 2** shows the clamp. This allows the use of a low-voltage transistor,

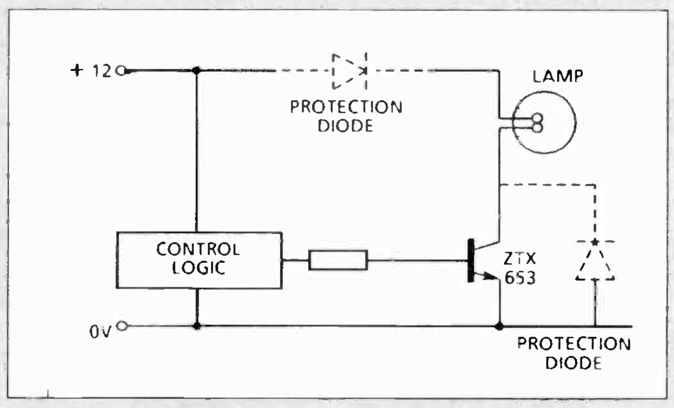


***Fig.1.** Two ways of preventing a back-connected battery blowing up the control logic.*

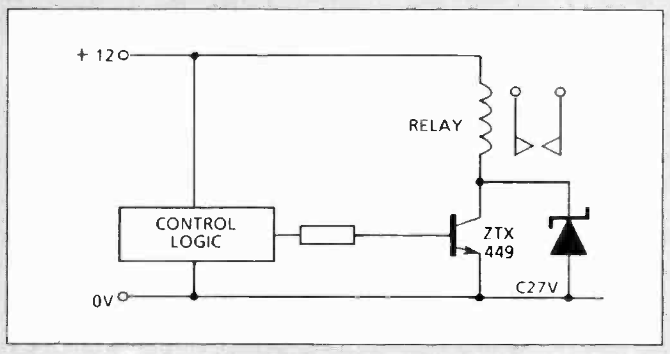


***Fig.2.** Parallel zener clamps 80V load-dump transient. The other way is to use a high-voltage transistor.*

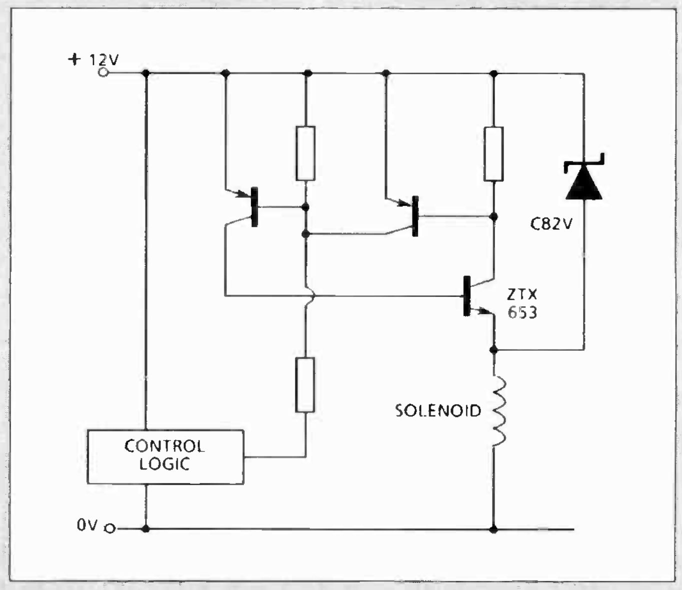
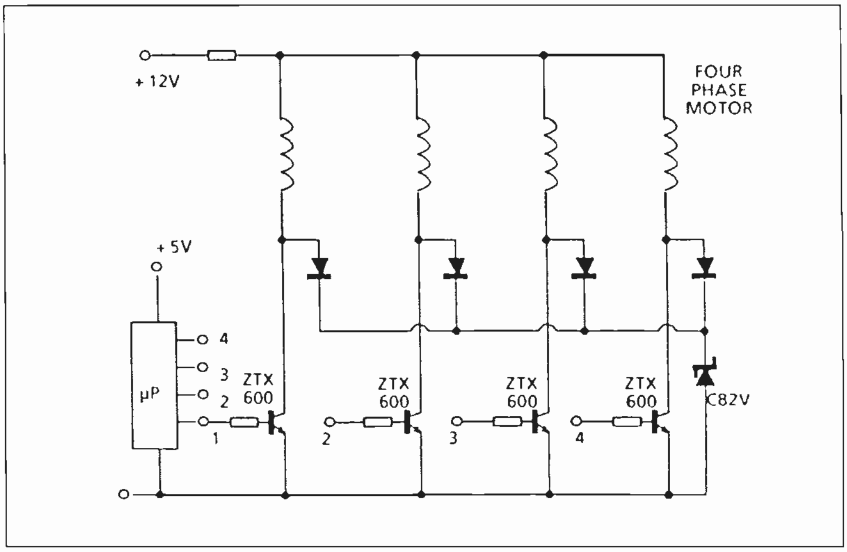


***Fig.3.** As a protection against shorts, this circuit imposes a current limit. The zener provides a clamp against transients.*

but the zener clamp has to take a current that is several times higher than in normal use, so is mainly used in low-current drivers. The high-voltage transistor option eliminates the need for a clamp for the 80V transient, but since 500V transients do appear, some type of clamp is still needed, albeit of much lower power since these high-voltage transients are of relatively low energy.

To protect the transistor against accidental shorts (the screwdriver in the socket), the circuit in **Fig. 3** imposes a current limit for a short time.

It is pointed out in the application note that lamps and relays can take up to 1A surge, so that the control IC, which uses low-current mos or cmos, must drive either an interface or high-gain transistors. Zetex says its mosfets, such as the *ZVN4206*, and darlingtons will replace the *ZTX449* in Fig. 2 to allow the use of low-current logic. **Figure 4** shows *ZTX600* darlingtons driving a four-phase stepper motor directly from a cmos microprocessor.



Zetex plc, *Fields New Road, Chadderton, Oldham OL9 8NP. Telephone 061 627 5476.*

Fig.4. Low-current cmos logic driving a four-phase stepper via ZTX600 high-gain darlingtons.

Accurate gain switching

It is convenient to use an analogue multiplexer to switch the gain of an instrumentation amplifier to accommodate varying signals. The multiplexer allows gain settings to be selected digitally. In ordinary use, the arrangement provides mediocre gain accuracy, since the on resistance R_{ON} of the multiplexer is added to the value of the gain-setting resistor.

On resistances can vary between 50Ω and 5kΩ, even the lower value being enough to cause trouble.

Burr-Brown's *INA120* instrumentation amplifier does not suffer from this particular problem. This diagram, taken from the B-B Applications Newsletter Vol 2 no 1, shows that gain-sense connections preserve accuracy when gain-switching circuitry is being used, internal gain-set and feedback resistors always being in series with no parasitic resistance in the loop. Multiplexer resistance is in series with the *INA120* high-impedance inputs and does not affect gain. The table shows the gain for a given input code; gain error will not exceed 1% over a full range of temperatures.

GAIN	SELECT CODE A1	A0	MEASURED GAIN ERROR (%)
1	0	0	0.05
10	0	1	0.08
100	1	0	0.10
1000	1	1	0.30

***Burr-Brown International Ltd**, 1 Millfield House, Woodshots Meadow, Watford, Hertfordshire WD1 8YX. Telephone 923 33837.*

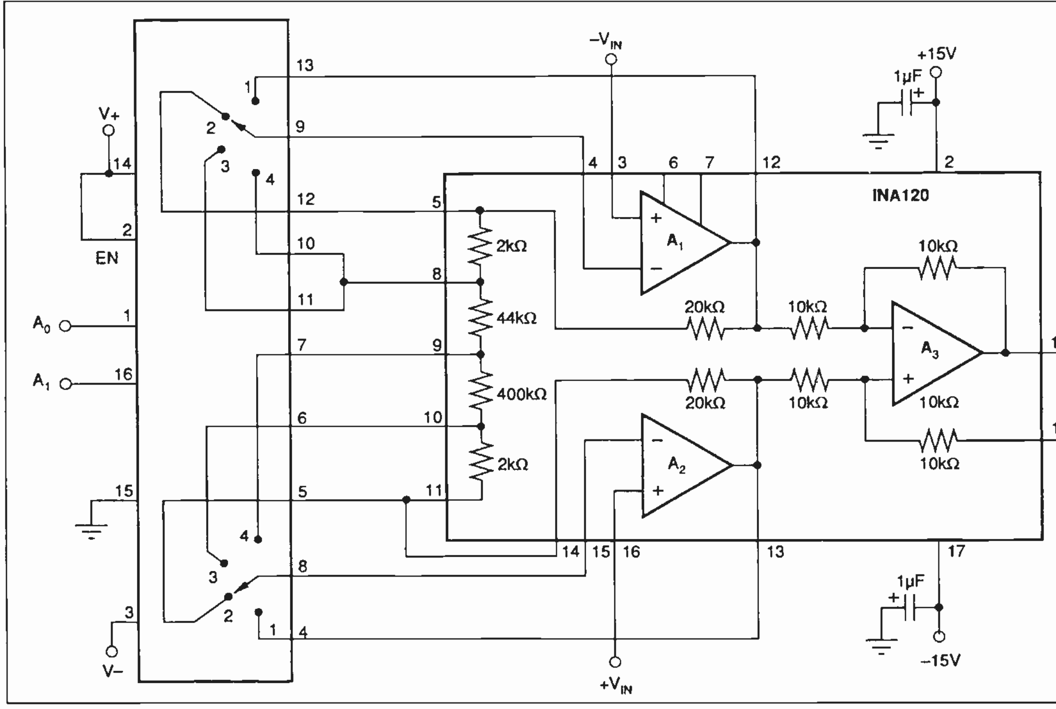


Fig.1. Using Burr-Brown's INA120 instrumentation amplifier with a multiplexer to set the gain avoids inclusion of multiplexer on resistance in gain-setting resistance.

IGBT audio amplifier

Insulated-gate bipolar transistors occupy a niche between bipolar and mosfet power transistors in that the on resistance is smaller than in mosfets and the transition frequency is higher than in bipolars. They have not yet made much of a mark in audio output stages, the mosfet being the "in" device, but Toshiba's Application Note X3504 gives full details of amplifier design using these devices.

To be fair, there is one drawback which is simple to avoid. In the design of IGBTs, an n-p-n parasitic transistor is formed, shown dotted in **Fig. 1**, which will cause latch-up if the collector current of the p-n-p bipolar output is allowed to exceed a given value.

If there is enough current through the p-base, the n-p-n transistor can be forward-biased and, with the p-n-p device, become a permanently conducting thyristor. A solution is the input n-p-n connection shown in **Fig. 2**, where the n-p-n base turns on if IGBT current exceeds a set amount and limits current to 16A pk, in case shown. The *GT20D101* is rated at 20A.

Toshiba's application note presents circuits by John Linsley Hood, in which bipolar, mos and insulated-gate bipolar transistors are used to give 40-80W at less than 0.05% THD. It is pointed out that, apart from the latch-up already mentioned, IGBTs are more robust than bipolars and not susceptible to the gate/source breakdown found in mosfets. Higher peak currents from IGBTs are of help when driving speakers with low impedance in parts of the audio band, since the need for secondary breakdown protection in bipolars and the fairly low current from mosfets can cause clipping.

Figure 3 is the circuit of a 40-80W amplifier using IGBTs. The note gives an analysis of the circuit design and a suggested printed-board pattern. Performance on a square-wave signal at 10kHz into a 2μF load is shown in **Fig. 4**. ■

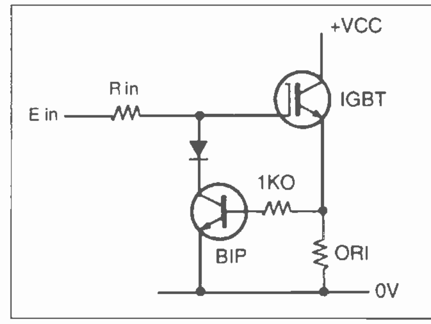


Fig.2. Latch-up protection. Input n-p-n transistor turns on if output current exceeds set limit.

***Toshiba Electronics (UK) Ltd**, Riverside Way, Camberley, Surrey GU15 3YA. Telephone 0276 694600.*

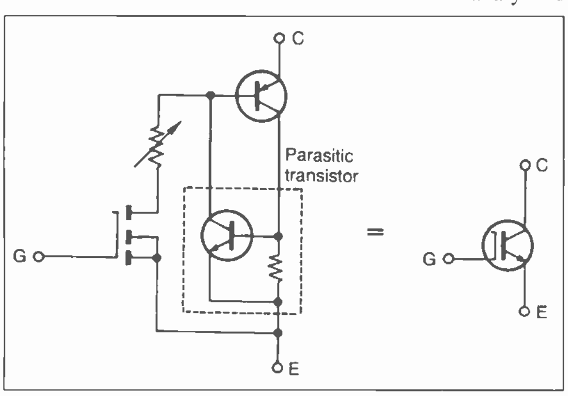


Fig.1. Effective structure of insulated-gate bipolar transistor (IGBT) and its symbol. Parasitic transistor shown dotted can cause latch-up without protection circuit.

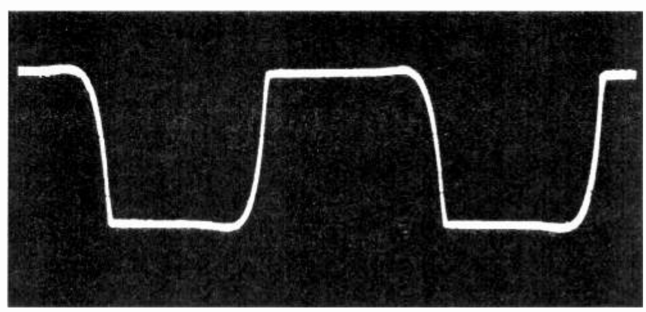


Fig.4. Square-wave output at 10kHz into 8μF load.

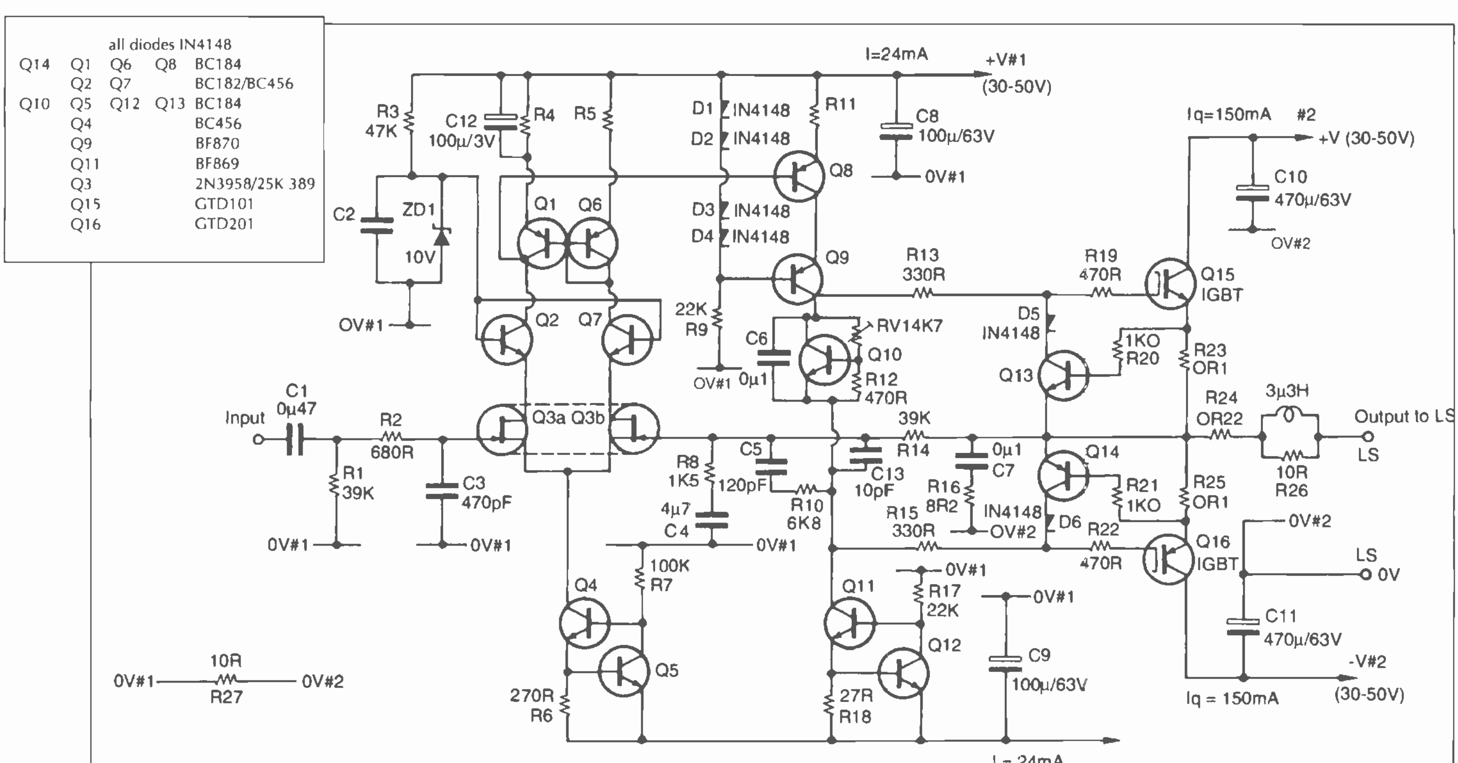


Fig.3. Complete circuit of 40-80W audio amplifier with IGBT output stage.

THE INVERTED WORLD OF GYRATORS

Dr C O Anazia shows how gyrator circuit components can mimic tunable inductorless analogue filters derived from their LC passive counterparts.

There is a wealth of material available for the design of passive LC filters. In theory these have lower sensitivity to component variations than do the active filter elements. Thus, if the inductors in an LC filter are replaced with gyrator circuits, the insensitivity to component changes in LC coupled filters may not be affected, so long as the gyrator model chosen adds no dissipative elements to the LC filter circuit.

Methods have been developed for the implementation of LC filters using active filter circuits like the biquad, state-variable or universal active filters. All of these approaches involve using the state equations to describe a second order transfer function. Higher order filters synthesised by using a cascade of bi-quadratic filter sections are sensitive to changes in the component variations in the bi-quadratic filter stages[1].

One innovative method adopted by designers to reduce the effect of component variation is the so-called leap frog design approach. This synthesises the LC filter directly from the state variable equations developed for the particular LC filter requirements.

The implementation is normally accomplished with integrators, summing amplifiers or analogue computers. Such filter implementations normally have the same low sensitivity to component variations as the corresponding LC passive filter. However, the leap frog circuit can become very complex for high order filters[1].

Operational amplifier gyrator circuits have been extensively described in the literature[2,3]. These gyrator circuit models can be used to simulate inductors when properly terminated. However, some of the gyrator models suffer from certain drawbacks such as instability, poor control of loss, sensitivity to component matching and complex circuit configuration that limits their practicality.

This paper describes a preferred gyrator circuit for simulating inductors and shows how it can be used in designing active filters from their LC passive filter prototypes. The preferred realisation tends to maintain the strong points of LC filter sections, unlike the componentsin active filter design.

Gyrator circuit models.

Many forms of gyrator circuits are available in the literature[1, 3, 4]. Some of these circuit models have one, two or even three operational amplifiers in the circuit realisation. **Fig. 1** shows three versions of a gyrator realisation, using operational amplifiers[1, 4].

Looking at node 1 of **Fig. 1a**, the input impedance can be derived as shown in equations 1-3.

At node 1:

$$I_1 = \frac{1}{R_1}(V_1 - V_3) \qquad ...1$$

At node 2:

$$\frac{(R_2 + R_3)V_1}{R_2 R_3} - \frac{V_2}{R_2} - \frac{V_3}{R_3} = 0 \qquad ...2$$

At node 3:

$$\frac{V_1}{R_4} + SC(V_1 - V_2) = 0 \qquad ...3$$

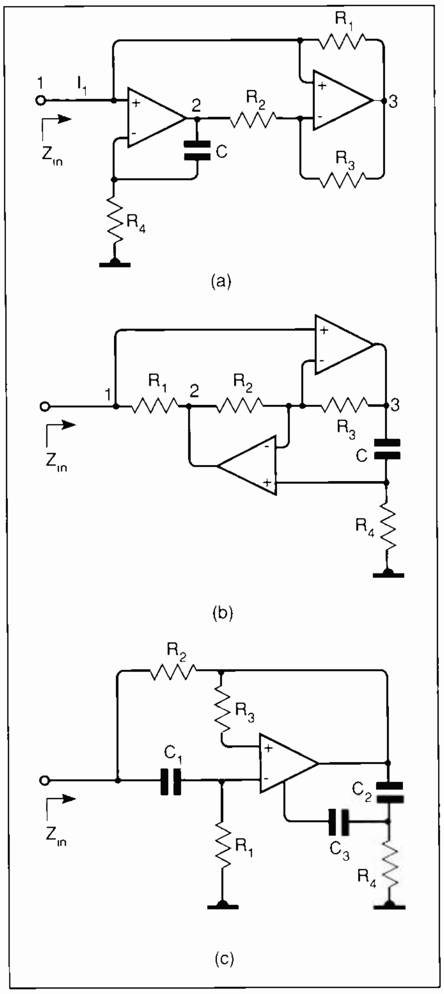


Fig. 1. Three realisations of a gyrator circuit using an op amp.

Solving equations 1, 2 and 3 to get the input impedance, we have:

$$Z_{in} = \frac{V_1}{I_1} = \frac{R_1 R_2 R_4 SC}{R_3}$$ where S is the complex frequency

The input impedance of the preferred gyrator realisation shown in **Fig. 1b** can be derived in a similar manner (see equations 4-8).

Hence, at node 1:

$$I_1 = \frac{V_1 - V_2}{R_1} \quad ...4$$

At node 2:

$$\frac{(R_2 + R_3)V_1}{R_2R_3} - \left(\frac{V_2}{R_2}\right) - \left(\frac{V_3}{R_3}\right) = 0 \quad ...5$$

At node 3:

$$V_3(1 + SCR_4) - V_1SCR_4 = 0 \quad ...6$$

Substituting [6] into [5], we have:

$$\frac{V_2}{R_2} = \frac{V_1(R_2 + R_3)}{R_2R_3} - \frac{V(1 + SCR_4)}{SCR_3R_4}$$

$$V_2 = \frac{V_1(R_2 + R_3)}{R_3} - \frac{V_1R_2(1 + SCR_4)}{SCR_3R_4} \quad ...7$$

Substiuting [7] into [4] to get:

$$I_1R_1 = V_1\left(\frac{R_2}{SCR_3R_4}\right)$$

gives

$$Z_{in} = \frac{V_1}{I_1} = \frac{SCR_1R_3R_4}{R_2} \quad ...8$$

The input impedance for the case of **Fig. 1c** has been shown[4] to be:

$Z_{in}=SC_1R_1R_2$, provided that R_2«R_2 and C_1»C_2»C_3.

Unity gain operation amplifiers which are also stable may be good enough.

Gyrators for grounded/floating inductors

In LC filter synthesis, inductors appear either floating or grounded. Grounded inductors can be simulated easily using the models of Fig. 1, particularly the preferred gyrator model of Fig. 1b. However, simulation of floating inductors requires two of each of the gyrator circuit models of Fig. 1 to be connected back-to-back[5].

In any case, for back-to-back configuration to yield stable results, the effective inductances of the two simulated inductors must be exactly equal, otherwise any unbalance would appear as a positive inductance to ground[5]. In practice, this requirement is not easy to achieve and may be impossible.

Alternatively, simulation of floating inductors can be achieved in another way. The realisation of Fig. 1b is preferred since it can easily be redrawn as shown in **Fig. 2.**

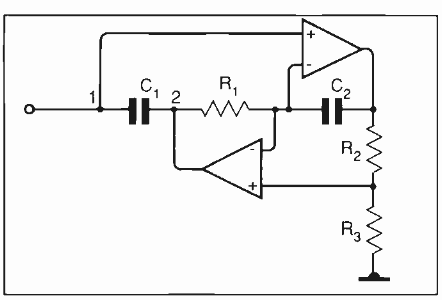


Fig. 2 FDNR circuit model realised by substituting a capacitor for R_1 in Fig.1b and by interchanging the component locations of C and R_3.

This is obtained simply by replacing R_1 with a capacitor and by interchanging the component locations of C and R_3 in Fig 1b.

The input impedance of Fig. 2 can be obtained from equation 8. That is, making the following substitution in equation 8:

$$\text{We let } R_1 = \frac{1}{C_1S}; R_2 = R_1; R_4 = R_3; R_3 = \frac{1}{C_2S}$$

$$\text{and } \frac{1}{SC} = R_2$$

$$\text{then } Z_{in} = \frac{R_3}{S^2R_1R_2C_1C_2} \quad ...9a$$

If we let $S = jw$

$$\text{then } Z_{in} = -\frac{R_3}{W^2R_1R_2C_1C_2} \quad ...9b$$

Equation 9b has the same characteristics as the impedance function, the so-called frequency-dependent negative resistance (FDNR). This has been derived in the literature [2,6] using other forms of gyrator circuit models for inductance simulation.

It follows that floating inductors can be simulated by employing the circuit of Fig. 2. This means that, in order to implement floating inductors in a passive LC filter realisation, we would first divide the impedance functions of all the filter elements by S, the complex variable, and then replace all the elements that have $1/S_2$ factor terms with Fig. 2.

Hence, resistors transform to capacitors, inductors to resistors and the circuit diagram of Fig. 2 replaces the capacitors. We can then state that grounded inductors can be simulated using Fig. 1b, which can be modified easily to simulate floating inductors.

Applying preferred gyrator circuit model

Two filter prototypes have been used to illustrate the procedure for simulating inductors. In one case, grounded inductors are predominant in the passive filter prototype employed; in another case, floating inductors predominate. It is assumed that a passive filter already exists to meet the design requirements.

Bandpass filter

An analogue bandpass filter, applicable to telephone channels, is to be designed. The specification for such a coupled resonator filter, shown in **Fig. 3**, are as follows:

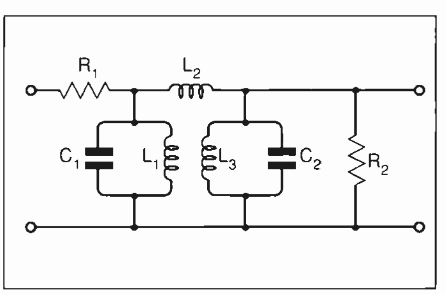


Fig. 3 Prototype of a coupled resonator bandpass filter.

Midband gain	=GdB
The high cutoff frequency	$=f_H$Hz
The low cutoff frequency	$=f_L$ Hz
The passband ripple	$=\alpha$dB
The input terminating resistor	$=r_1\Omega$
The output terminating resistor	$=r_2\Omega$

From the literature[7] we can deduce a number of expressions, necessary for calculating the design parameters (see box):

$$w'_o = \frac{f_s}{f_c} \text{ where}$$

f_s, the geometric centre frequency $= (f_Hf_L)^{\frac{1}{2}}$ Hz

f_c, the bandwidth at the cut-off frequencies $= (f_H - f_l)$Hz.

$$\text{Let } n = \frac{r_1}{r_2}$$

$$h = \frac{1}{10^{\alpha/20}} \quad ...10a$$

$$k = 2(1 - h^2)^{\frac{1}{2}} \quad ...10b$$

$$p = \left[\frac{n^2 + kn + 1}{n(2 - k)}\right]^{\frac{1}{2}} \quad ...10c$$

$$A = \left[k(1 + p^2)\right]^{\frac{1}{2}} \quad ...10d$$

$$\text{Then } G = 20\log\left[\frac{1}{n^{\frac{1}{2}}}\frac{p}{1 + p^2}\right] \quad ...10e$$

From the procedure available in the literature[7], the design parameters in Fig. 3 can now be determined (see equations 11-16).

$$\text{Thus } r_1 = nr_2 \quad ...11$$

$$C_1 = \frac{w'_0A}{w'_sr_1n^{\frac{1}{2}}} \quad ...12$$

$$C_2 = \frac{w'_0A}{w'_sr_2n^{\frac{1}{2}}} \quad ...13$$

$$L_1 = \frac{n^{\frac{1}{2}}r_2}{c_1w'^2_sn^{\frac{1}{2}}r_2 - w'_sP} \quad ...14$$

$$L_2 = \frac{(r_1r_2)^{\frac{1}{2}}}{w'_sP} \quad ...15$$

$$L_3 = \frac{(r_1r_2)^{\frac{1}{2}}}{C_2w'^2_sn^{\frac{1}{2}}r_2 - w'_sP} \quad ...16$$

The *Pi*-network of inductors in Fig. 3 can be realised with two gyrator models of Fig. 1b. This realisation is shown in **Fig. 4**. For optimum gyrator performance, the amplifiers should be closely matched. Quad-type packaged amplifiers may be used so as to maintain the same amplifier environmental characteristics. Design parameters in Fig. 4 can be obtained by using the results derived earlier for Fig. 1b.

In particular, if r_1=r_2, all the capacitors in Fig. 4 may be assigned a convenient value (see equations 17a - 18c).

$$C_1 = C_2 = C_3 = C_4 = C \quad ...17a$$

Hence, using equation 13:

$$c = \frac{w'_0A}{w'_sr_2} \quad ...17b$$

From equation 8, derived using Fig 1b,

$$L_1 = \frac{CR_1R_3R_4}{R_2} \quad ...17c$$

Hence, $R_4 = \frac{R_2L_1}{CR_1R_3}$ ...18a

If we chose $R_1 = R_2 = R_3 = R$

then $R_4 = \frac{L_1}{CR}$ ...18b

The value of R should be large enough to minimise amplifier loading. Similarly:

$$R_6 = \frac{L_3R_8}{CR_7R_9} \quad ...18c$$

R_5 in Fig. 4 is a coupling resistor and can be chosen to be of a variable resistance so as to be tuned to balance the amplifier sectors. Since the coupling in the circuit of Fig. 3 is a function of ratio L_2/L_1, R_5 can be varied such that

$$\frac{R_5}{R_4} = \frac{L_2}{L_1} \quad ...19a$$

Then, using equation 18b, the order of magnitude of R_5 can be established.

Thus

$$R_5 = \frac{L_2}{CR} \quad ...19b$$

It may be equally desirable to make R_1 a variable resistor, in which case R_1 is chosen so that $R_1 \pi R$. Tuning the filter to achieve resonance at the design centre frequency can be achieved by tuning R_1. Determination of the design parameters in Fig. 4 is now complete.

Passive low-pass filter

Figure 5 is a 5-stage Tchebycheff low-pass filter prototype. This prototype has a cut-off frequency, a terminating resistance and passband ripple characteristics. The component values have been chosen so that the filter would have a cut-off frequency of 1Hz, a terminating resistance of 1Ω and a reflection coefficient of 20%, corresponding to a passband ripple of 0.177dB.

To convert the normalised parameter values of Fig. 5 to their actual values, we simply multiply all the capacitors by

$$\frac{1}{R_C^{w}}$$

and the inductors by

$$\frac{R}{w_c}$$

where R in Ohms is the terminating resistance, and w_c in rad/s is the cut-off frequency[8].

It is obvious from Fig. 5 that the inductors are floating; as such the simulation of the inductors can be accomplished by using the gyrator circuit model of Fig. 2. The resultant realisation is shown in **Fig. 6a** and the symbolic representation is shown in **Fig. 6b**. Here, all the inductors are now resistors, the terminating resistor becomes a capacitor and

Table 1: calculated performance characteristics

Passive LP filter Frequency (kHz)	Magnitude (db)	Phase (°)	Gyrator realisation Magnitude(db)	Phase (°)
50	-1.6705902	-73.0111	-1.6705902	-73.0112
100	0.40957767	-151.632	0.40957373	-151.632
150	1.6116123	-114.815	1.6115863	-114.815
200	-17.744099	-44.017	-17.744087	-44.016
240	-30.138199	-56.778	-30.138187	-56.777

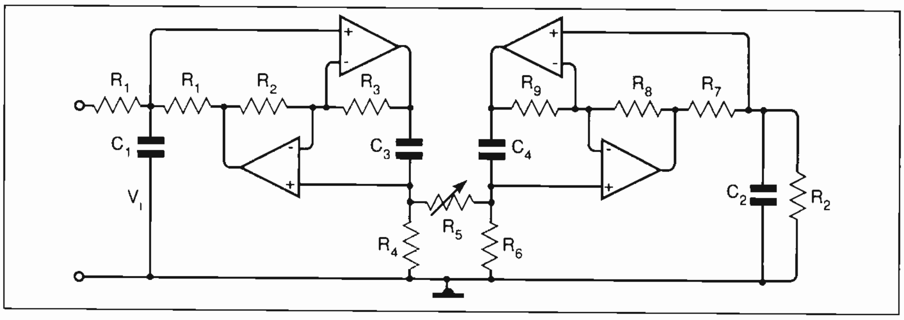


Fig. 4 Gyrator realisation of bandpass filter from Fig.1b.

the capacitors are FDNRs, designated G_1 and G_2. Note that we obtain Fig. 6 by dividing the impedance functions of all the elements of Fig. 5 by the complex frequency variable S and then replace all the

$$\frac{1}{S^2}$$

terms with the FDNR of Fig. 2.

The transfer function of the passive filter in Fig. 5 can easily be derived (see equations 20a to 20g).

$$H(s) = \frac{V_o}{V_i} = \frac{SC_1}{S^6y_6 + S^5y_5 + S^4y_4 + S^3y_3 + S^2y_2 + Sy_1} \quad .20a$$

where

$$y_6 = L_1C_1^2\frac{(C_2L_2L_3)}{R} \quad ...20b$$

$$y_5 = c_1^2c_2L_1L_2 \quad ...20c$$

$$y_4 = \left[L_1C_1(C_1L_3 + C_1L_2 + C_2L_1) + C_1C_2L_2L_3\right]/R \quad .20d$$

$$y_3 = C_1\left[L_1(C_1 + C_2) + C_2L_2\right] \quad ...20e$$

$$y_2 = C_1\frac{(L_1 + L_2 + L_3)}{R} \quad ...20f$$

$$y_1 = C_1 \quad ...20g$$

In deriving the transfer function for Fig. 6, equations 21a to 21c can be written.

$$V_i = f_1R_1 + G_1(f_1 - f_2) \quad ...21a$$

$$f_1 = \frac{f_2(G_1 + R_2) + G_2(f_2 - V_o^{sc})}{G_1} \quad ...21b$$

$$f_2 = \frac{V_o\left[1 + sc(G_2 + R_3)\right]}{G_2} \quad ...21c$$

The expressions for G_1 and G_2 are of the form shown in equation 9. Using the subscripts in Fig. 6, we obtain:

$$G_1 = \frac{R_6}{S^2R_4R_5C_1C_2} \quad ...22a$$

$$G_2 = \frac{R_7}{S^2R_8R_9C_3C_4} \quad ...22b$$

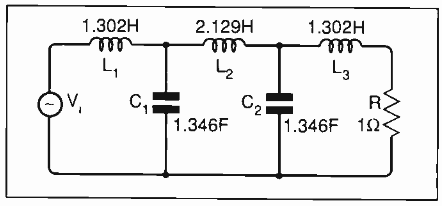


Fig. 5 Prototype of a five-stage lowpass Tchebycheff filter. The circuit's inductors are floating.

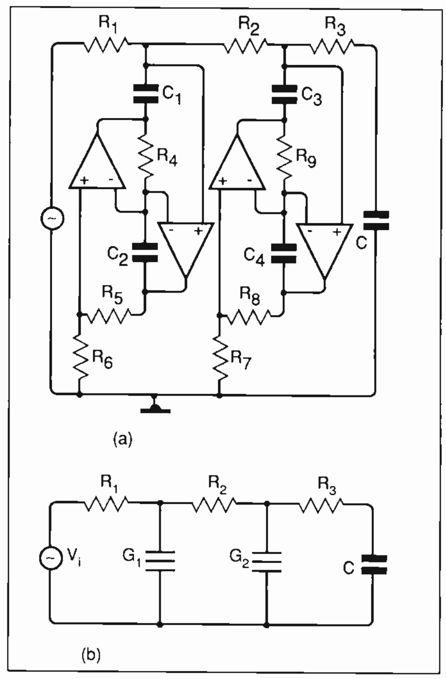


Fig. 6. Gyrator circuit model derived from the circuit of Fig. 2. Fig.6a is the realisation that results; fig. 6b is the symbolic representation.

Substituting equation 22 into equation 21, we obtain, after some computation, the expression for the transfer function as follows:

$$H(s) = \frac{K}{S^5 y_6 + S^4 y_5 + S^3 y_4 + S^2 y_3 + S y_2 + K} \quad \ldots 23a$$

where $y_6 = R_1 R_2 R_3$ ...23b

$y_5 = R_1 R_2$ ...23c

$$y_4 = \frac{CR_3 R_6 (R_1 + R_2)}{y} + \frac{CR_1 R_7 (R_2 + R_3)}{y_1} \quad \ldots 23d$$

$$y_3 = \frac{R_6 (R_1 + R_2)}{y} + \frac{R_1 R_7}{y_1} \quad \ldots 23e$$

$$y_2 = \frac{CR_6 R_7}{y y_1}(R_1 + R_2 + R_3) \quad \ldots 23f$$

$y_1 = R_8 R_9 C_3 C_4$ ...23g

$y = R_4 R_5 C_1 C_2$ ...23h

$$k = \frac{R_6 R_7}{y y_1} \quad \ldots 23i$$

Simulation

Computer simulation runs were carried out on the passive filter in Fig. 5 and the gyrator implementation of Fig. 6. For the computer simulation of Fig. 6, we choose

$C_1 = C_2 = C_3 = C_4 = C = 0.01\mu F$.

If the component values in Fig. 5 have been normalised to the desired cut-off frequency and terminating resistance, then we can define the FDNR-gyrator impedance values

G_1^* and G_2^*

Thus

G_1^* and G_2^*

represent FDNR impedance values obtained by multiplying the normalised capacitance values in Fig. 5 by the chosen value in the gyrator model. The normalised inductance values in Fig. 5 are equally divided by the chosen value of capacitance, which for this simulation is 0.01µF.

Since

$G_1^* = G_2^*$

we may choose

R4 = R5 = R8 = R9 = 1.5kΩ

Then the following resistance values in Fig. 6 can be related thus:

$$R_6 = \frac{y}{G_1^*} \quad \ldots 24a$$

$$R_7 = \frac{y_1}{G_2^*} \quad \ldots 24b$$

where y and y_1 are defined in equation 23.

In general, gyrator resistance R_4 is chosen equal to R_5. These gyrator resistances are chosen so that their values are much less than the specified input impedance of the operational amplifiers employed. Resistances R_8 and R_9 are similarly chosen. Also the gyrator capacitance values are chosen so as to provide high input impedance as derived in equation 9 at all frequencies of interest.

Figures 7 and **8** show (respectively) the magnitude and the phase performance characteristics that result from the simulation of the two filter circuits of Fig. 5 and 6, taking 15kHz as the cut-off frequency. Here, cut-off frequency is the terminal frequency of the ripple channel and the conventional 3dB cut-off point. The results are seen to agree favourably. In fact, their differences have been exaggerated somewhat for clarity. **Table 1** shows the extent of similarity between the simulated prototype filter and the gyrator model for a cut-off frequency of 150kHz. The passband ripple obtained is 0.1774153dB as opposed to the assumed value of 0.177dB.

It is important to note that varying the gyrator resistances by about 20% does not significantly affect the results. This means that the resistors used in the gyrator circuit model can have wider tolerances. Hence, resistors are less worrisome which could be a useful feature for an integrated circuit fabrication of the gyrator circuit model.

The same statement cannot be made for the capacitors in the gyrator circuit, however. It is observed during the computer simulation runs that a 5-10% change in the capacitor value changes the characteristic of the realised gyrator filter model compared with the prototype filter when the gyrator capacitance is changed by 5%.

Electrostatic capacitors are generally regarded as "true" pasive components. This means that to maintain the capacitors' tolerance range of the capacitors used in the gyrator realisation, electrostatic capacitors (eg, ceramic), which exhibit low temperature coefficients, are preferable to electrolytic capacitors. Hence, the capacitors used in the gyrator circuit model should have low percentage tolerance in addition to having low temperature coefficient behaviour.

Circuit sensitivity to capacitance variation can be reduced by other means. For example, a resistor may be selected that has temperature coefficient equal, but opposite in sign, to that of the capacitor, so that the RC product exhibits a temperature coefficient that is approximately zero. ■

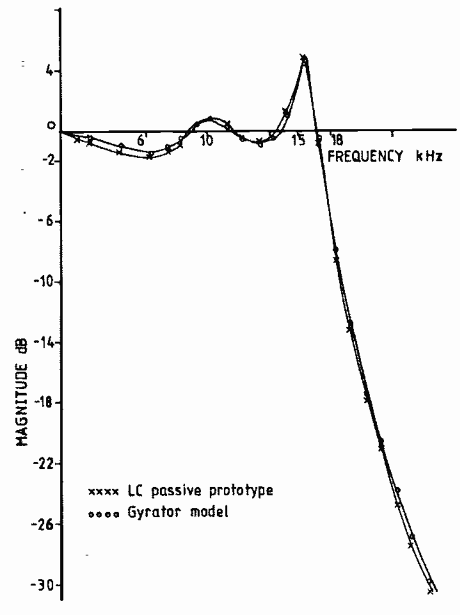
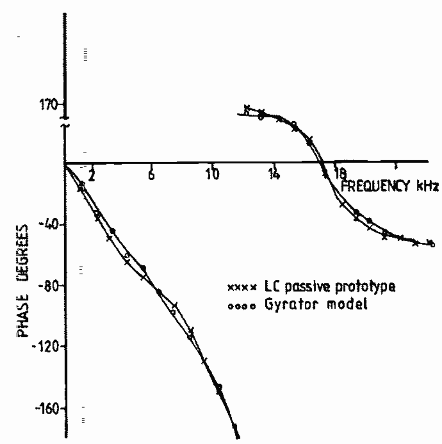


Fig. 7. Magnitude characteristics and Fig. 8 (below) phase characteristics, of a simulated filter derived from the simulation of the circuits in Figs. 5 and 6. 15kHz has been taken as the cut-off frequency.



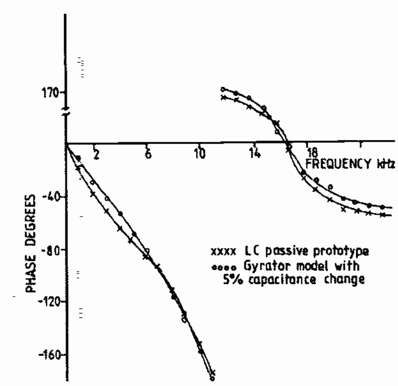


Fig. 9. Phase characteristics of the gyrator filter model compared with the prototype filter when capacitance is changed by 5%.

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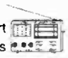

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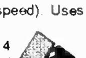

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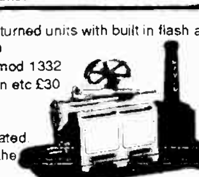

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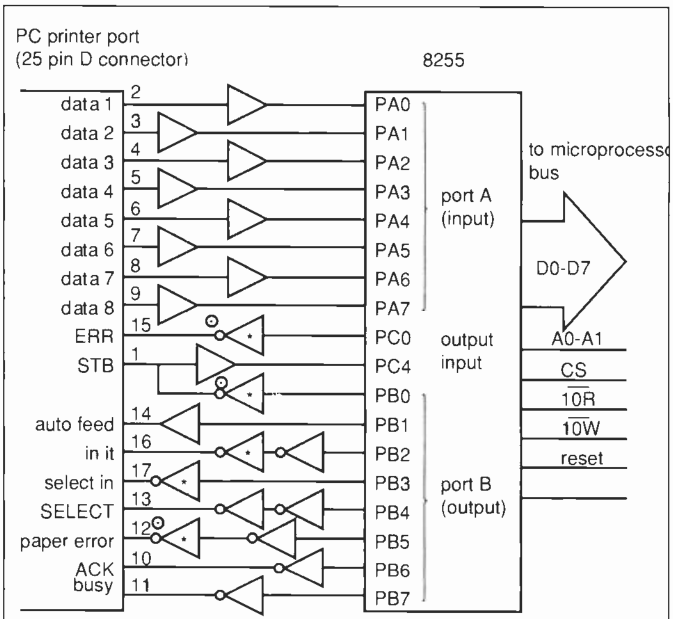


1 pull down 47k at data 1 to data 8
2 * open collector inverter 7405/06
3 inverters CD 4049 and non inverting buffers CD 4050
4 O pull up 4k7

Fig.1. PC printer port used for external data reads. This 8255 PPI handles data transfer under control of micro.

0378H	output (data port) pins 2-9
0379H	input five lines (D3-D7) pins 15,13,12,10 and 11
037AH	output four lines (D0-D3) pins 1,14,16 and 17. D4 enables
IRQ7	
037AH	input four lines (D0-D3) bidirectional
0378H	input; pins 2-9 can only read data on data port.

Assuming a base address 0378H for the set of five ports in the standard, the table gives address and direction.

Input and output lines of 037A share the same pins. Output lines of 037A are buffered by open-collector gates and may be kept off by setting 04 on this port. In this condition, these four lines and the five at port 0379H can be used for the external data, with one line available for direction testing.

Input data is read at two ports and possibly in one 16-bit read operation. Bits are compiled to organise the input data byte; in some cases, inverters are needed. **Figure 1** shows an interface using a programmable peripheral interface *8255* controlled by a microprocessor to handle data transfer. The PC tests direction by sensing the ERR line.

Flow charts for both PC and host are at **Figs. 2** and **3.**

R N Misra
Physical Research Laboratory
Navrangpura
Ahmedabad India

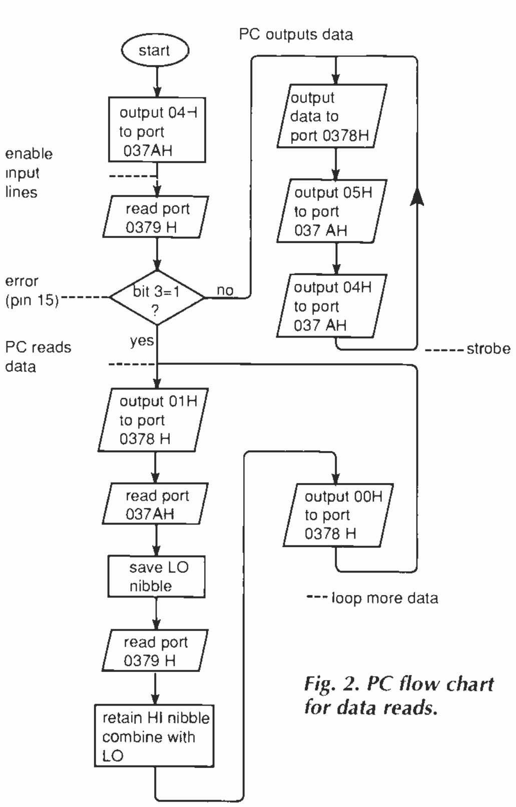


Fig. 2. PC flow chart for data reads.

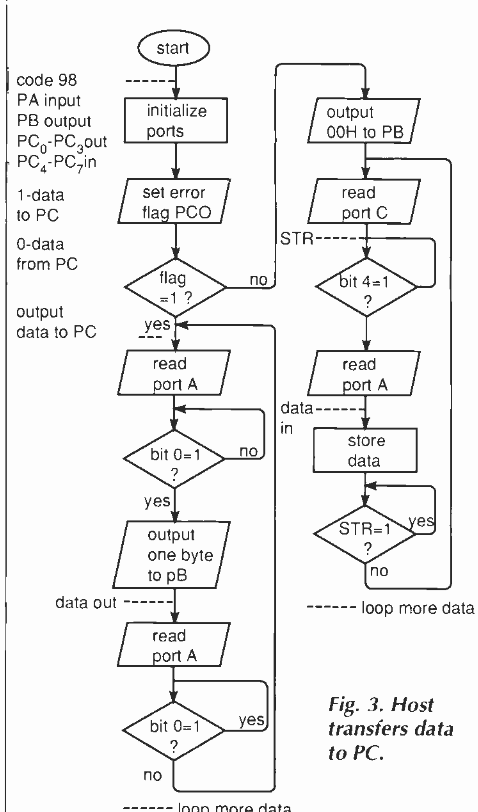


Fig. 3. Host transfers data to PC.

Diode probe thermometer

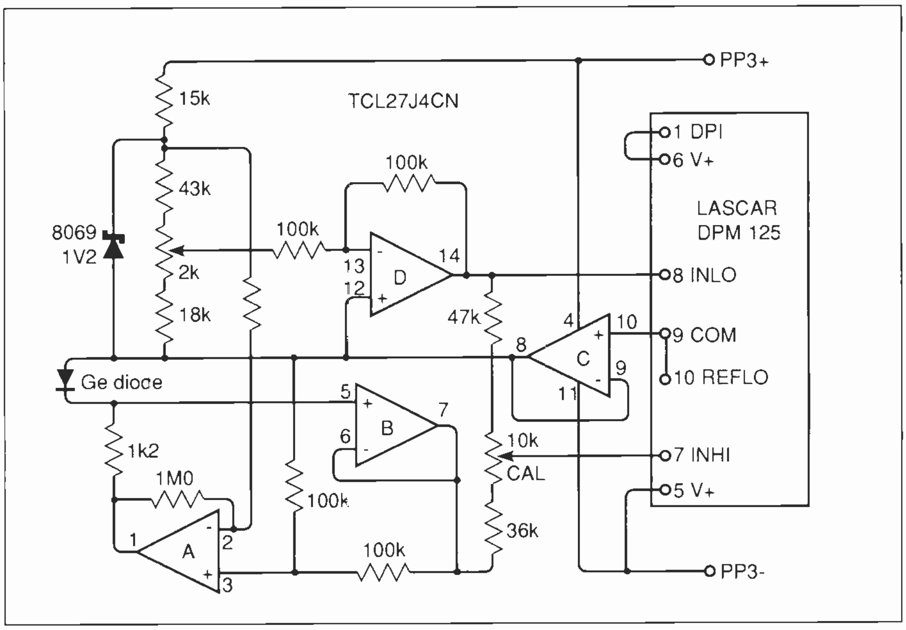
I have based this design on that by Henderson (*Wireless World*, June 1981, p. 50) to exploit the low drift and low current needs of the Texas TLC series op-amps. It uses an inexpensive 3.5-digit, 200mV display to give a stable 0.1°C resolution reading of temperature from –25°C to 125°C.

Op-amps A and B compose a constant-current source for the probe, defined by the 8069 bandgap reference and 1.2kΩ resistor, B also providing the positive meter input by way of the calibration pot. Op-amp *C* buffers the 0V rail to the circuit, keeping it at 2.8V below battery voltage as determine by pin nine of the DPM (if other DPMs are used, this voltage may need to be obtained by other means). Zeroing is via op-amp D.

I used cermet multi-turn pots and 1% metal-film resistors. If a silicon probe diode is used, the pot chains may need modification. Calibrate the instrument at freezing and boiling points of distilled water; the zero pot adjusts the freezing point reading, to be set first, and then the calibration pot for the boiling point.

The diode cathode goes to the probe tip for quick response. A length of thin-walled 3mm OD tube (an old telescopic aerial) forms the probe shaft with a length of 36SWG wire soldered inside to pass through the tip with the diode for the cathode connection. The other end takes a 2.5mm phone jack.

H Maidment
Salisbury
Wiltshire



Diode probe thermometer with digital readout measures from -25°C to 125°C5

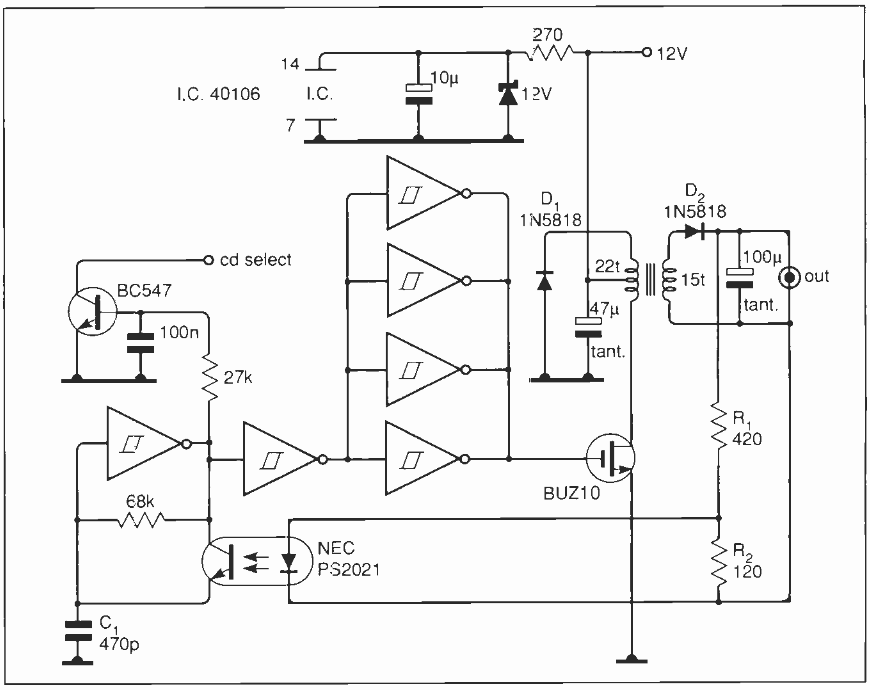
Power for car audio

Separating signal and power supply grounds in car audio equipment can present a problem, a frequent solution to which is to provide a kind of floating supply by means of a switching PSU. The circuit shown has a true floating output which is used to supply 700mA at 5V to a portable CD player.

Voltage feedback from the flyback converter output is taken by way of an opto-coupler, the values of R_1 and R_2 being chosen to suit the NEC *PS2021* device. The *BC457* open-collector stage signals power on in the CD player to switch the audio path with no loss of efficiency, since it monitors oscillator duty cycle. Capacitor C_1 may be increased to work with other toroids at lower frequencies.

A prototype oscillates at 40-65kHz, depending on the load; regulation and stabilisation are better than 5% and efficiency is about 70%.

Paolo Palazzi
Cervignano
Italy



Flyback converter with opto-coupled feedback gives floating power supply for car audio equipment.

Simultaneous insertion and return loss plots

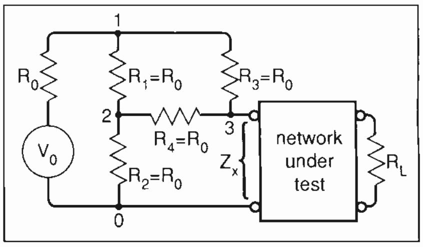
Using an analogue simulator to plot branch currents and node voltages of a network can provide a plot of insertion loss or gain as a function of frequency. To obtain the driving-point impedance and therefore reflection coefficient p and return loss 20log≥ ρ≥ needs more computation. It is, however, a simple matter to model a return-loss bridge at the relevant port, the bridge acting as a generator to plot insertion loss and return loss at the same time.

Figure 1 shows the model. In this form of Wheatstone bridge, voltage across the horizontal V_{32} is in proportion to the reflection coefficient relative to R_o at Z_x:

$V_{32} = [(Z_x - R_o)/(Z_x + R_o)](V_o/8) = \rho V_o/8$.

The network sees the bridge as a voltage source $V_o/2$ and R_o, corresponding to the ideal return loss bridge with 6dB insertion loss. To plot insertion loss, there must be a source of 2V instead of $V_o/2$, so $V_o = 4$ and $V_{32} = \rho/2$. Adding a voltage-gain source with a gain of 2, feeding it with V_{32} and taking it to an unconnected node gives a voltage equal to ρ; a decibel plot of this node voltage gives return loss.

C J Hall
Giubiasco Switzerland



Modelling a return-loss bridge at the relevant port allows plot of insertion loss and, without further computation, return-loss plot simultaneously.

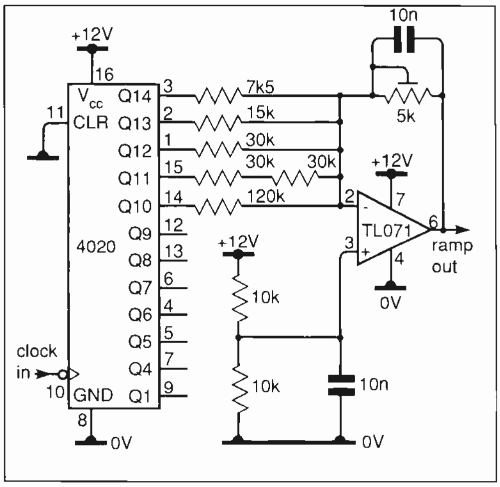
Slow ramp generator

Ramp times of more than a few seconds have a tendency towards variability of time constant, since the capacitors used are electrolytic and therefore relatively variable. To make a ramp with a period of 16384/clock frequency, when a five-bit resolution is acceptable, use the circuit shown here. All the resistors specified can be had in 1% tolerance to give a linearity to within 1LSB.

Since the *4020* is a 14-bit ripple counter, switching glitches are evident and are smoothed by the 10nF feedback capacitor, which may be larger if required to eliminate the steps in the output. Ramp amplitude is controlled by the 5kΩ variable resistor. If you need the ramp to drive a comparator, you can leave out the amplifier altogether and simply put a smoothing capacitor on the comparator input.

As shown, the output is a negative-going ramp, which may be inverted by using inverted *4020* outputs; and to further exploit the circuit, the counter could be replaced by an up-down counter to give sawteeth or triangles.

A H Millar
Witney
Oxfordshire



Simple circuit to give slow ramps, in cases where an electrolytic timing capacitor would be on the vague side. The 4020 is a 14-bit up-down ripple counter.

Rechargeable battery tester

As a nicad rechargeable battery ages, its capacity decreases and its time to recharge increases. This circuit tests the capacity of a battery.

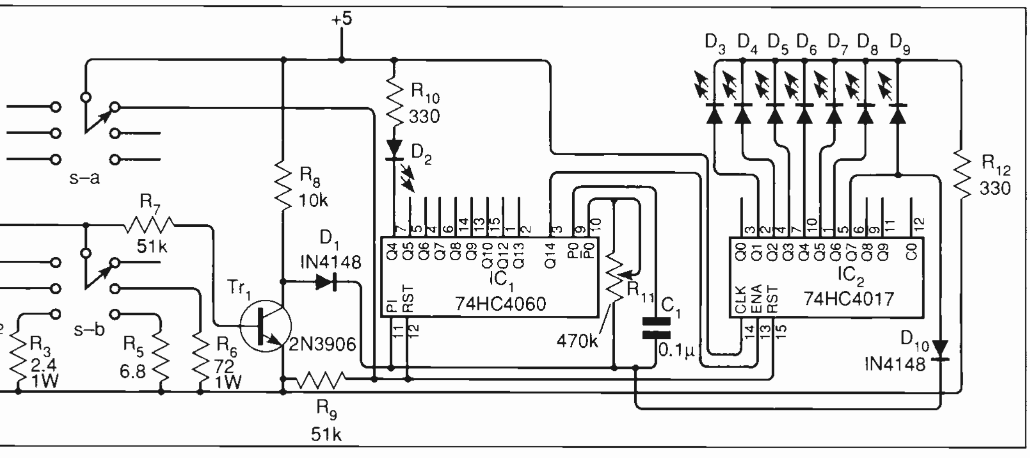
Fully charged, new 9V, *AAA*, *AA*, *C* and *D* batteries have capacities of 0.1, 0.18, 0.5, 2.2 and 4AH respectively; the switch selects the appropriate resistor to discharge any of these types at the one-hour rate. The *4060* is a 14-stage binary counter with a built-in oscillator whose frequency is determined by R_{11} and C_1, adjusted so that Q_{14} emits a pulse every 12 minutes to the *4017* decade counter. At the same time, Q_4 supplies a 1.4Hz signal to the led D_2, which shows that the circuit is in operation.

Oscillation is under the control of the battery voltage; if that is higher than 0.9V, Tr_1 saturates and holds D_1 off – if it is low enough to cut off Tr_1, D_1 comes on and stops the oscillator and therefore the signal to D_2.

At this point, D_{3-9} show the battery's capacity of between 20% and 140% in 20% steps. When D_9 is on, its Q_7 drive from IC_2 stops the oscillator by means of D_{10}, so that D_9 is on continuously when the battery voltage is at least 40% higher than normal.

Yongping Xia
Torrace
California
USA

Circuit to indicate capacity of nicad rechargeable batteries in terms of percentage of normal capacity. Batteries are discharged at one-hour rate.



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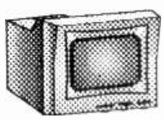

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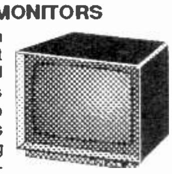

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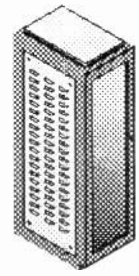

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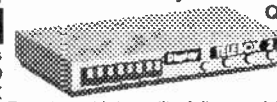

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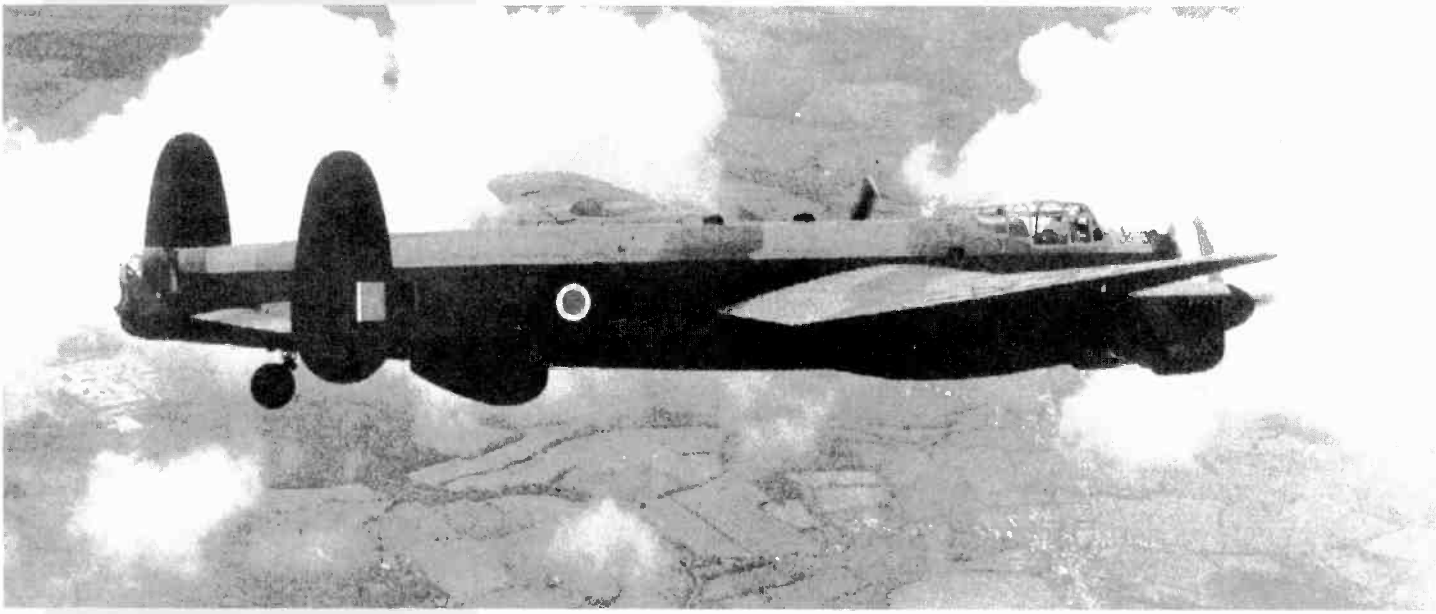


Photo courtesy: Lynn Williams

In 1939, the UK government was offered a design for what appeared to be an accurate, foolproof air navigation system which The RAF desperately needed. It was turned down. Phillip Darrington narrates a story of an unsung inventor's brilliance and the official indifference to an electronic navigation system which might have saved many allied airmens' lives.

PURSUING A LOST COURSE

Area bombing of Germany during World War II has been called into question constantly since peace broke out in 1945. Sir Arthur "Bomber" Harris has been vilified because he concentrated on centres of population instead of "surgically" destroying military targets. The proposed erection of his statue next to that of "Stuffy" Dowding is opposed by those who consider the destruction of German cities a crime.

But did he have a choice? Bomber Command started the war with its navigation in such a state that, if crews managed to get to within about ten miles of the target, they were doing reasonably well. Gee and Oboe came and, when the Germans jammed them, went, although each lasted many months. Even the early Pathfinder Force had its problems, losing six of the twelve aircraft on its first sortie and not even finding the target. Any thought of precision bombing was impossible; there was desperate need of an accurate, unjammable navigation aid.

Yet at least one neglected piece of development would, if it had been seriously considered, almost certainly have saved civilian and service lives and possibly cut short the war. A lone inventor, with no formal engineering or science education, came up with an innovative navigation system but was turned down flat, only to see his work taken up much later and developed by commercial concerns to the point where it now earns millions of pounds a year – too late to save lives and far too late to affect the course of the war. The rejection also now means that this country pays royalties to American companies for equipment that could have been produced here many years before anyone else was able to.

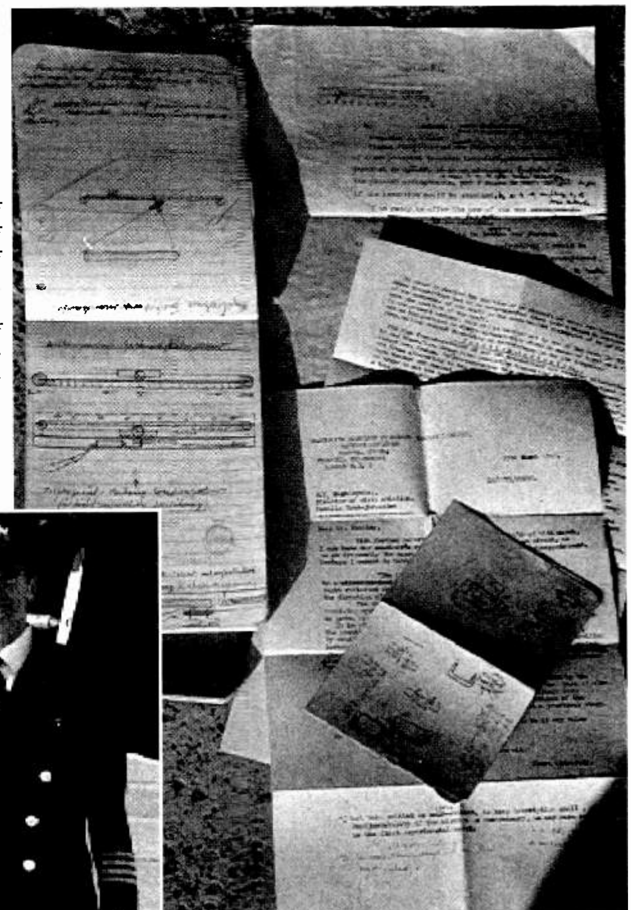
In December 1939 Heinz Lipschutz, who was working for the Department of Civil Aviation at Lydda Airport, Palestine, in meteorology and flight control, offered the British government a design for automatic position-finding equipment for use in aircraft. He was 20 at the time and unskilled in either English (he was born in Germany) or in formal specification writing, describing only one of several variants of his system and omitting features and requirements that seemed to him obvious. The outcome was a total failure by the examiner at Marconi, to whom the matter had been passed, to understand that "obvious" parts of the design had not been described in detail. He seized on these "omissions" and concluded that they invalidated the whole thing, even though alternatives were included which rendered his remarks irrelevant.

A letter from Marconi to the Director of Civil Aviation at Lydda (Lipschutz was not accorded the simple courtesy of a personal reply) is on record and quotes the examiner's opinion: "...there are a number of other solutions of the same problem, none of which, so far as I know, have reached a practical stage. I therefore do not consider the invention to be of any value to us." Evidently, if none of the others was any good, then neither was this one.

According to Lipschutz, who later became an airline captain with Cambrian Airways after being co-founder of Kol Israel, the Israeli national broadcasting station: "I only offered them one of the ideas – the one using radio. It was just a trial balloon. If they'd been at all keen, I would have given them an inertial navigation system.

Such systems are now in widespread use, but he was dissuaded from offering that, too, by Max Offner, engineer in charge of the Palestine Broadcasting Service, on the grounds that it was "...too revolutionary.... might fall into the wrong hands or not be appreciated." On the available evidence, he was probably justified on that last point.

Lipschutz tried his hardest to provide such a system and even built a simplified prototype while confidently awaiting an assessment of his trial system from London. "By that time, I was working with the RAF and was saddened to see those lads flying off on raids with no real method of finding their target... such a

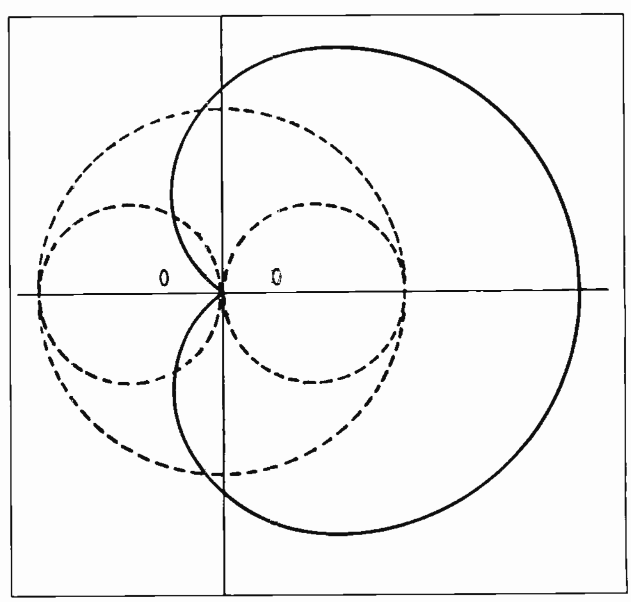


A page from Capt. Lipschutz's notebooks of 1939, showing a number of sketches of his method of moving the "rolling map". Other notes – of which there are many – show details of gyros based on magnetic levitation and servo systems to harness their data.

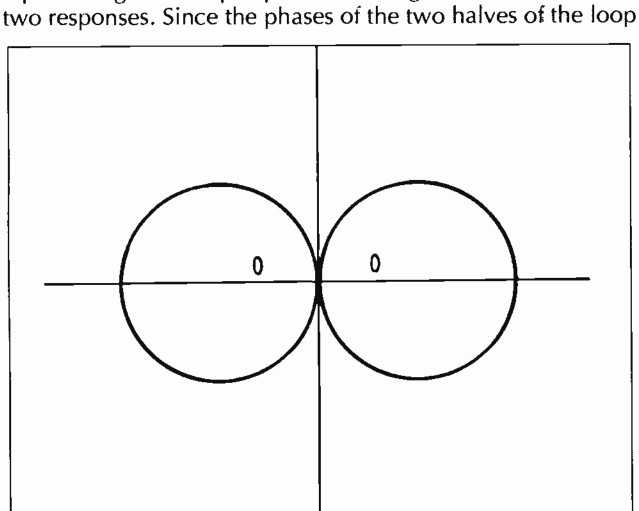
SIMPLE CONCEPT

Direction finding by means of a loop aerial is simple – at least in theory. Its polar diagram shows that a signal from a transmitter in the direction of a null will almost completely vanish, the direction thereby being easily determined. Fairly obviously, however, there are two nulls in opposite directions, so that there would be no means of discovering whether the transmitter was north-east or south-west.

The solution is to use a co-sited omnidirectional aerial with a polar diagram of equal phase and magnitude and sum the two responses. Since the phases of the two halves of the loop



Combined omni and loop polar diagram, showing heart-shaped field. Cardioid null is not quite as sharp as from loop alone and is usually used merely to show which way to turn loop for correct null. This is unnecessary in Lipschutz's design. Signal from omni must be exactly the same in magnitude and phase as that from the loop.



(Left). Loop aerial exhibits a figure-of-eight field diagram. Signals coming from directions of each minimum effectively vanish.

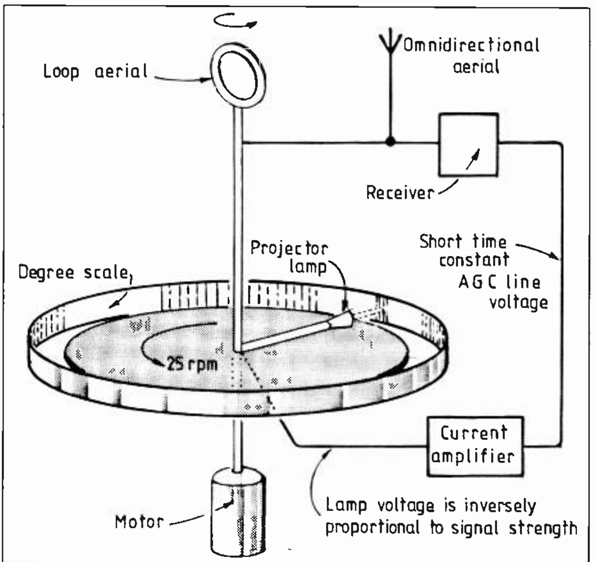
waste of lives. And even if they did find the target, they still had to get home again, sometimes injured and with a badly shot-up aircraft".

In essence, Lipschutz's first, trial system was a development of the common direction-finding loop aerial. At that time, RAF navigators had to rotate a loop aerial manually, while listening to the transmitter on headphones. At one point in a revolution (actually two, but the correct one is normally indicated by using a non-directional aerial to add its signals on one side and cancel on the other) the signal vanishes to give a definite indication that the aerial is pointing broadside to the transmitter, the direction of which is thereby located. Repeating the performance with another transmitter gives two known directions and therefore a position.

In theory, this is perfect; in practice, in the presence of ionospheric reflection, interference, aircraft engine noise and often a lack of familiarity with the equipment, it was less than ideal. An inaccuracy of anything up to five degrees was normal. After 400 miles, a five-degree error would put the aircraft about 35 miles off track, although further readings would reduce that distance.

Lipschutz not only automated the process and realised its potential accuracy, but went on to provide such a display of which navigators could only dream: a moving point of light or two crossed light beams on a map which gave an instant position, with no calculation or operational effort. Further, by providing the correct maps for the whole of a trip and plotting the required course on the map in a thickish line, the appearance of the light on one side of the line or the other would indicate drift. This information could have been detected by photocells and used by an autopilot for hands-off flying. Alternatively, the amount of drift could be used to obtain true wind-speed. "All the techniques, apart from a couple, were known and there was no reason it could not have been fairly easily produced."

Apparently, the objections raised by Marconi's were that no one else had been able to do it and that changing the maps along the track would cost too much. One can think of no fitting reply to the first and Lipschutz points out that his method of avoiding the cost of map-changing and other adjustments as the aircraft progressed (a "rolling map" was proposed) had been ignored. This simple scheme was completely compatible with the method of automatic navigation that Lipschutz was to describe to the authorities when they had examined his simpler system. It was to use inertial input from accelerometers to form



Elementary scheme of radio navigator, showing one of two turntables. Light bulb flashes once each revolution when signal from aerial is at minimum, indicating direction of transmission on scale.

are different, summing gives a heart-shaped or cardioid polar diagram. There is now only one null, although not as sharp as that of the loop alone. In manually operated systems, this means that the cardioid effect can only be used to indicate the direction in which to turn the loop to obtain the correct null. But in the Lipschutz device it can be used as the direction-finding null. There was, in fact, provision made to switch out the sense aerial once the correct null was identified and use the sharper loop-aerial null, but this was not found to be necessary.

An Adcock aerial was also proposed with a view to reducing polarisation error.

Lipschutz started by addressing the problem of turning the loop and detecting a null automatically. The loop and omni aerial signals were summed to give the required polar diagram, amplified and used to drive an incandescent bulb mounted on an arm which revolved horizontally at the same speed as a the loop aerial.

Current from the power amplifier was controlled by the signal-amplifier AGC voltage and was therefore in the opposite sense to the aerial signal voltage; the bulb lit only when the aerial null was pointing at the transmitter.

Encircling the arm was a scale on which Lipschutz had marked degrees, so that each time the aerial pointed at the transmitter, the bulb lit and indicated the direction to that transmitter. Since the aerial and arm were both spinning 25 times per minute, direction indication was effectively continuous.

Switching of the light on and off was not instantaneous, so that the spot of light as the arm revolved was broadened, but the centre of the spot was still easy to determine, since it was at its brightest at the centre. It was for this reason that the relative lack of sharpness in the aerial null was unimportant.

Going on from this, Lipschutz arranged the spinning arm under a translucent map with its axis under a known transmitter. He inclined the beam of light from the bulb slightly upwards and focused it into a thin line on the map. The result of this was a map of the relevant area with a line of light pointing to the transmitter (in fact, the reciprocal was taken, so that the light beam came from the transmitter). Two such arrangements, with the signal from the aerial commutated to feed each once per revolution and with each having its centre below the position on the map of a transmitter produced two light beams which crossed at the position of the aircraft. The slides from which the maps were projected were so arranged that two relevant transmitters were always at the corners of one side of the map display, to avoid having to change the arm centres.

Version submitted to government

In the version Lipschutz sent for consideration by the government in December 1939, the effect was identical to that described above, but now there were means for avoiding the effects of interference and short signal breaks. Two separate "resolvers" were used: one to indicate direction as before and another to act as a servo to move a "rolling map", removing the need to change maps en route.

In the direction indicator, the signal amplifier produced a high-power pulse at the aerial null, the pulse being taken to a distributor, which fed the current pulse to a solenoid on the end of a counterbalanced arm rotating at the speed of the aerial.

Above the arm was a ring of 360 soft-iron pole-pieces, so that as the aerial revolved, the pole-piece corresponding to the null direction became magnetised. A counterbalanced, metallic arm above the ring, free to rotate about the centre of the system, was attracted to the magnetised pole-piece and, since the arm carried a lamp and mirror, indicated direction by a line of light, as before.

A commutator switched between distributors and a second light-arm produced the second beam to give the position of the aircraft. The centre of the field always corresponded to what was effectively a modern inertial navigation system (INS), now widely used by all large aircraft, but in 1939. The system never left the drawing board except as a prototype for presentation to the authorities in the event of his trial radio system being accepted. It was never heard of by the government of the day and can only be seen in the fifty-year-old sketches in Lipschutz's notebooks.

Both systems had been worked out in minute detail. Techniques such as magnetic recording and magnetic levitation, both now common, were needed for stability and frictionless response, and were used and described – all this in 1939. Capt. Lipschutz has only recently felt able to mention all this to anyone, as he says he has no wish to find himself pigeonholed with all the world's eccentrics.

This tale of missed opportunity and leaden-headed failure to seize on a chance of saving lives is not uncommon, but there is a difference. Capt. Lipschutz has no chance of making any money out of a fifty-year-old invention, now used widely. Nor is he at all interested in making his name; he is now 72 and has had a successful and fulfilling career in other fields. He says he is simply saddened by the fact that his deeply frustrating and baffling experience of rejection at such a time is still such a familiar story.

As a politician in the recent election campaign pointed out, a huge number of modern innovations are British – integrated circuits, holography, body scanners, liquid-crystal displays and a mass of other technologies in everyday use – but are manufactured somewhere else. The argument then was superficially about sustained funding for research and a Minister for Science, but the fault is deeper. Clearly, nothing would be gained if the outcome of such research were to be further innovation – but ignored in Britain and exploited to the full abroad. The cure, if one is possible, lies in a total change in attitude and a willingness to accept that the unfamiliar is not necessarily the unworkable.

Meanwhile, Heinz Lipschutz is getting on with building a light aircraft. He has already spent 34 years trying to persuade our naval experts that his design for a radically different type of submarine – the U-plane, a small-hulled, heavier than water craft which 'flies' through the water on hydrofoils – should at least be investigated, only to see his ideas taken up by Americans, Russians and, ironically, Germans, who are believed to have a prototype.

Nothing, it appears, changes. ■

the signal minimum and therefore the sharpness of the null was still unimportant. The magnetic field lasted for two revolutions of the arm, so that in the event of a signal loss, the arm would still take up and maintain its previous position.

Each pole-piece could be demagnetised, in the event that pole pieces having the ideal hysteresis characteristic were not available, by an RF coil mounted on the arm in time for a new pole-piece to be magnetised on each second revolution. A compass-controlled differential gearing mechanism was intended to compensate for turns made by the aircraft, so that the indication would be independent of the aircraft heading.

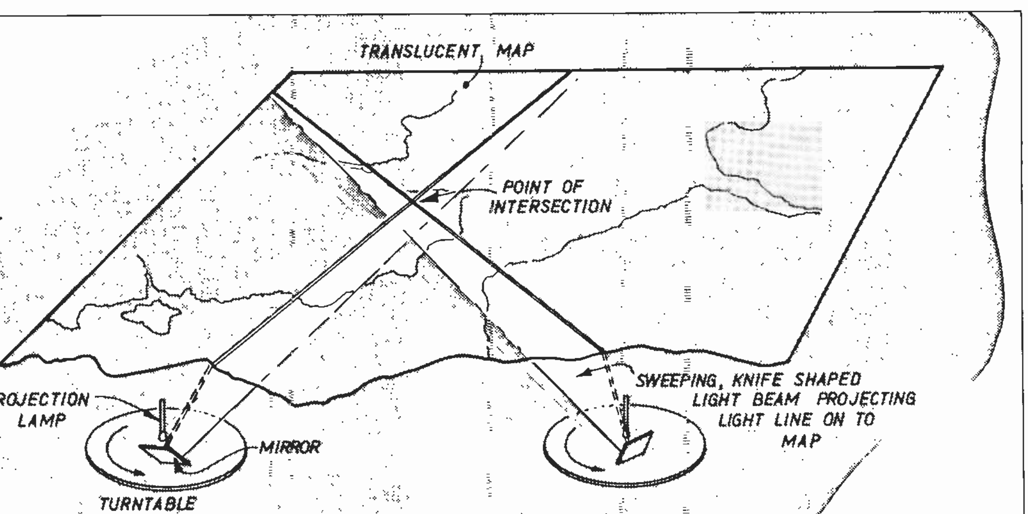
A further enhancement was the rolling map. In this variant, the ring of pole-pieces was replaced by a ring of 360 coils with their terminals protruding beneath. Instead of the coil on the revolving arm, contacts conducted current from the power amplifier to each coil in turn and magnetised the coil corresponding to the direction of the transmitter. Here, the increased magnetic field of the system was powerful enough to move metallic arms connected together by loosely fitting sleeves, so that both arms were free to move relative to each other, the crossing point being effectively the aircraft position. But, although a vertical light beam from the crossing point would then give the position, the movement of the sleeves was intended mainly to provide information to a servo on the position of the aircraft over the map and to move the continuous map on rollers along the route, thereby avoiding any possible problems with map changing and matching with transmitter positions. Additionally, the information would provide ground-speed and drift data directly. This point was fully covered in the submission, but totally ignored by the examiner.

This forward and backwards movement of the map and sideways movement of the arm crossing-point would have made it a simple matter to implement an inertial system by feeding the outputs of accelerometers to each servo, the light at the crossing point still indicating position. Such a system would either supplement the radio system in conditions of interference or loss of signal or could be drift-corrected by means of the radio system. Such a system was indeed the original impetus for the design of the equipment, the radio version being submitted as less of a shock to the governmental system and more likely to be understood and considered. A prototype was well advanced when Lipschutz was told that his work was not wanted.

Many other points were put forward – far too numerous to go into here – but the fact remains that this was a workable design, requiring no new technology and capable of quantity production.

What was new was the "magnetic recording" aspect of the device, for that was exactly the principle used in centring the light arm. Also, there was the suspension of the mechanical (self-integrating inertial) accelerometers by magnetic levitation, as was the intended use of magnetic bearings for the spinning gyros, before its time by a matter of twenty years or more.

Two tables with mirrors to reflect focused light from bulbs onto underside of translucent map, producing two crossed lines of light. Turntables and bulbs are centred on positions of known transmitters on map.



Circuits, Systems & Standards

First published in the US magazine EDN and edited here by Ian Hickman.

Op amp provides phase-locked loop

Equalling the performance of a classical phase-locked loop in some applications, this oscillator is frequency-modulated directly by the input signal's phase relation to the oscillator output, obviating the usual separate phase comparator, integrator and linear voltage-controlled oscillator.

To picture this "loop," first consider operation of the basic oscillator (**Fig. 1**). Op-amp output is a square wave formed by R_F charging C_F to the hysteresis voltage at the non-inverting input. When the inverting input crosses this non-inverting input, the output changes state accordingly: R_F must now charge C_F, in the opposite direction.

When the output's state changes, the voltage at the non-inverting input moves in the same direction – it takes time for the voltage on C_F to cross it again. The time for two such crossings constitutes one cycle period.

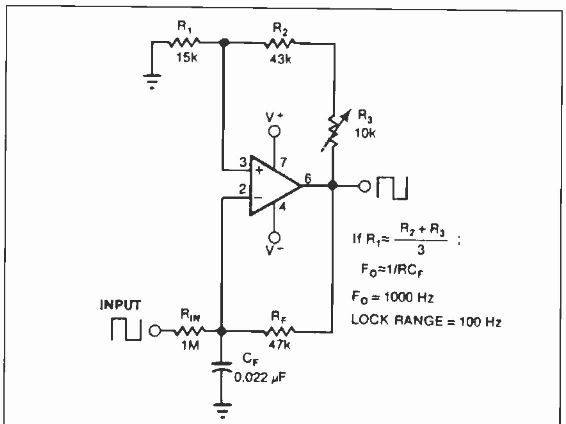


Fig. 1. Oscillator circuit, frequency modulated by the phase relation of its input signal to its output signal.

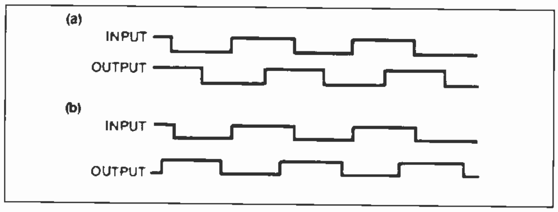


Fig. 2. An input signal of the same frequency (a) as the oscillator's frequency aligns the phase relationships so that the net effect is zero; (b) decreasing the input frequency hinders CF's charging, causing a decrease in the oscillator's frequency.

Applying an input signal equal to the oscillator's free-running (centre) frequency at R_{IN} (**Fig. 2a**) aligns the output's phase relation so that the input's influence on the charging of C_F half aids the output (in phase) and half hinders it (out of phase). The net effect is zero.

If the input frequency decreases, the input tends to lag the centre-frequency phase (**Fig. 2b**), hindering the charging and resulting in a corresponding decrease in output frequency. With an increase in input frequency, the phase tends to lead, pulling the output frequency with it. A 90° input lead or lag exerts the maximum influence: beyond 90° the influence cannot hold phase lock.

Phase lock occurs within one cycle and has no overshoot. The phase settles to equilibrium with a time constant inversely proportional to lock range. The lock range equals the capture range and is proportional to input amplitude: it varies as an inverse function of R_{IN}.

Response to odd harmonics in this circuit is the same as to the fundamental, but response to odd sub-harmonics drops off in lock range in proportion to the square of the frequency.

Response to waveforms other than a square wave is similar, but generally weaker. For a given frequency and lock range, the normalised settling time constant is 1 for square waves, 1.5 for sine waves and 2 for triangle waves.

Temperature stability, from –30 to +70°C, is better than 0.2% of F_0, for film resistors, a ceramic C_F and a *CA3130* op amp. This variation can be largely compensated by a diode network in place of R_1 or R_F.

***Ralph Wilbur**, Vega Electronics, El Monte, CA*

Op amp PLL

Lab bench audio sine-wave generators typically include a sync input, to allow the output frequency to be locked to a given frequency low level signal if manually tuned to approximately the same frequency. In the case of a square-wave generator, the locking action can be described in terms of a phase-locked loop, as this article shows. Note that if a square-wave output is desired, the mean DC level at the input must be round: alternatively, the input may be DC blocked.
IH

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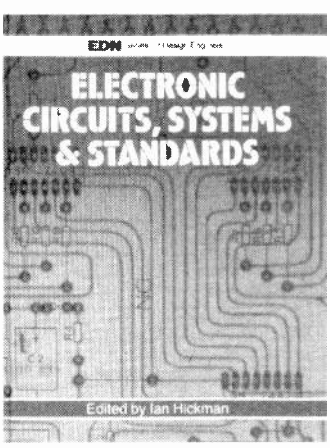
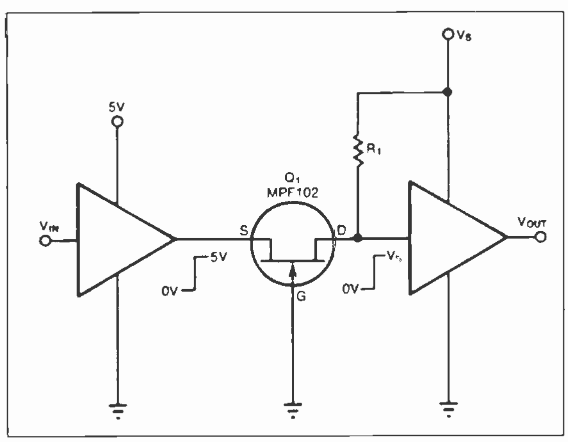


Jfet serves as low-power logic translator

The figure shows a simple method for translating a 5V logic signal to the 12 or 15V level required by certain cmos ICs. Transistor Q_1 is an n-channel jfet operating in the common-gate mode. A source voltage above 1 or 2V pinches the jfets channel off and allows R_1 to pull the drain voltage to V_S. A source voltage near 0V turns the channel on, which places the drain near 0V as well.

R_1 determines the circuit's speed and power consumption. Values from 100kΩ to 1MΩ draw approximately 150 to 15μA and set a practical pulse-rate limit of about 1MHz. This circuit consumes less power than one based on a bipolar transistor, and it does away with one part (the base resistor).

Timothy R Wolf, *Microwave Systems, Lancaster, PA*



The jfet, operating in the common-gate mode, provides low-power translation of a 5V logic signal to higher-voltage levels.

Simple non-inverting logic level translator

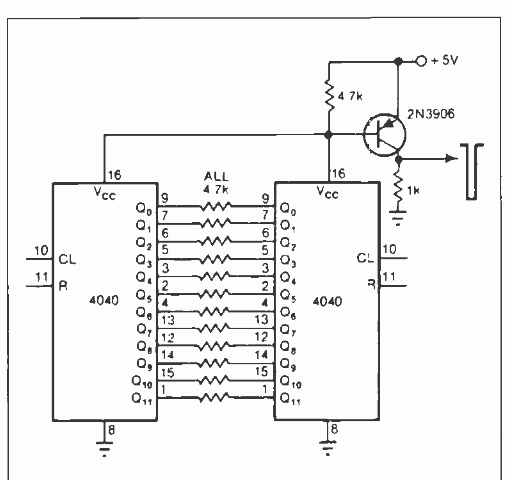
A bipolar transistor makes a fine logic level translator, but is inverting. This translator is not – and uses fewer components.
IH

Replace exclusive Ors with resistors

Designers commonly need a signal that indicates when counter outputs are identical. You could employ exclusive-Or gates to provide this indication; however, a more economical solution requires only two cmos counters, such as the 404012-bit binary devices shown in the figure. Tie the respective outputs together via resistors; a transistor emitter-base junction supplies power to the counters and monitors current consumption.

When the outputs of both counters are identical, no current flows in the resistors. Because cmos circuits inherently consume only μA, the transistor lacks base drive and turns off, producing a negative-going pulse.

George Breindel, *Custom Chronograph Co, Tonasket, WA.*



No current flows through the resistors when the counter's outputs are identical.

Simple twelve-bit comparator

EDN readers have fertile imaginations, and here is another circuit gem. If one of the counts is fixed or can be presettable, then that counter can be replaced by hard-wired straps or DIL switches.
IH

ACTIVE

A-to-D & D-to-A converters

Video A-to-D converter. CXD1175AM/AP by Hakuto is an 8-bit converter using a two-step parallel system for low-power working. In a conventional flash converter, 256 comparators are used, consuming up to 400mW at 20MHz; this one uses 32 comparators and takes 60mW. A reference voltage for self bias and sample-and-hold facilities are built in. Hakuto International (UK) Ltd, 0992 769090.

Linear integrated circuits

Low-EMI line receiver. Common-mode rejection of 90dB at 60Hz (85dB at 20kHz) provides a high degree of immunity from interference in the SSM-2143 differential amplifier from Analog Devices. It complements the SSM-2142 balanced line driver recently introduced for audio and industrial use. Slew rate is 10V/μs, THD 0.006 and gain either -6dB or 6dB, the selection being by reversing input and output reference connections. Analog Devices, 0932 232222.

60MHz op-amp. Elantec's EL2044 is a 60MHz bandwidth, 325V/μs op-amp having an output swing of ±13.6V on a ±15V supply. Output current is 75mA. Voltage feedback is used to maintain stable working in the presence of capacitive loads or feedback components. It is claimed to be suitable as an up-graded replacement for the Analog Devices AD847 or the National Semiconductor LM6361. Kudos Thame Ltd, 0734 351010.

PWM modulators. Five pulse-width modulators from Linear Technology, the LT1241/2/3/4/5 family, are intended for use in 500kHz off-line power supplies, being pin-compatible with the standard UC1842 devices. All the usual circuitry is incorporated and there is a high-current totem-pole output to drive power mosfets. Current sense delay is down to 50ns and start-up current is less than 250μA. The 500kHz operation is made possible by the elimination of cross-conduction current spikes, and blanking on the current-sense comparator eliminates a filter by preventing the leading-edge spike from tripping the comparator. Micro Call Ltd, 0844 261939.

Bi-cmos video switch/amp. CA3256 consists of five analogue switches, a 2-to-4 decoder and a buffer amplifier and is meant for general-purpose video signal control. Four channel switches are digitally controlled, led output drivers allowing for indication of the On channel, while the independent fifth channel may be used for other purposes or to monitor the other channels. Feed-through of the switches is typically -66dB at 5MHz, and insertion loss of the Onswitch is 0.8dB. Gain is externally adjustable and unity-gain bandwidth is 25MHz. Thame Components Ltd, 0844 261188.

Logic building blocks

Datacomms controller. HD64570 serial communications adaptor from Hitachi is a 7.1Mbit/s, low-power and low-cost device. It possesses a two-channel multiprotocol serial comms interface to support modes such as asynchronous, byte synchronous and bit synchronous modes such as HDLC and SDLC. Fifo buffers are 32 bytes deep and allow high throughput when coupled with the DMA controller, which supports chain transfers in bit-synchronous mode for auto buffer switching. Hitachi Europe Ltd, 0628 585000.

Memory chips

Static rams. Goldstar Electron GM76C256L 32K by 8 SRAMs are meant for low-power use, taking a mere 2nA, and have access times of 85ns. Chip select and output enable are provided. The units are in SO-28 surface-mounting packages. Flint Distribution Ltd, 0530 510333

I^2C 8K eeprom. National Semiconductor's new family of eeproms includes an 8K device for the first time in this technology. The NM24C** devices are cmos types for use in battery-powered equipment. Organised in four pages, the eeproms have standard, two-wire serial interfaces for simplicity and, using a bidirectional data transfer protocol in 16-byte page-write mode, operate a 5ms self-timed write cycle. Jermyn Distribution, 0732 740100.

Video ram. Samples of Micron's 2M2 (256K by 8-bit) video ram, the MT42C8255, are now available. Serial access time is 22ns and the

Optical devices

Printer laser diode. A visible-light laser diode from Hitachi, the HL6713G AlGaInP device, is meant particularly for laser printers and operates at 675nm, with an output variation when pulse-driven of less than 10. The Metal Organic Chemical Deposition process used not only improves image quality in printers, but avoids the use additional b as current due to the ow "droop" characteristic. Astigmatism is down to 5μm. Hitachi Europe Ltd, 0628 585000.

unit supports split-read transfer, serial output, non-persistent masked write block write and fast-page mode. The units are for use in graphics and imaging systems and also in Super-VGA displays. Micron Technology (UK) Ltd, 344 360055

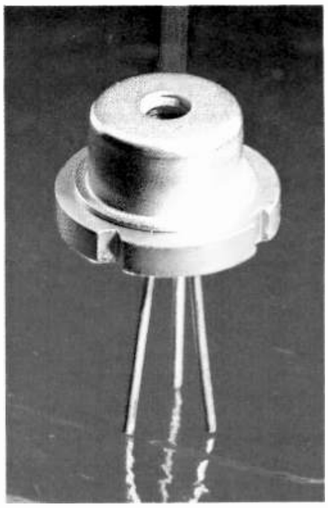
9-bit fifos. MU9C0591/1902/2903/4904 are cmos first-in-first-out memories by Music Semiconductors, and are arranged as 512/1024/2048/4096 by 9 for use in systems in which a parity bit is employed. Access time is 20ns, cycle time 30ns and the units offer simultaneous and asynchronous Read and Write port operation. Expansion in width or depth requires no external logic and there is no performance penalty. Flags indicate full, empty and half-full. Mogul Electronics, 0732 741841.

Microprocessors and controllers

Single-chip PC. Two devices from Sharp, which it calls "embedded engines", are effectively IBM-compatible PC XTs one one chip. LH72001 has seven of the important interface circuits, including dos in rom, and the unit is based on a NEC V20 microcomputer. Also built in are keyboard, printer and memory-card interfaces and a memory controller for drams, srams and pseudo-rams. External memory capacity is 1Mbyte rom and 16Mbyte ram. It works at 8MHz. LH72/73 embedded engines use the NEC V20 and V30 respectively and also contain a channel-less gate array with up to 50,000 raw gates for macrocell integration Sharp Electronics (Europe)GmbH 010 49 40/23 76-0

Mixed-signal ICs.

Motor drive. Two full-bridge PWM motor drivers, the UDN2953B and



UDN2954W, are available from Allegro, formerly part of Sprague Technologies. They provide bidirectional control of DC or stepper motors at up to 2A output current and peak start-up of up to 3.5A on supply voltages of 50V. Full protection is included, and when the reference voltage falls to below 0.8V, a braking condition is provided. Allegro MicroSystems, 0932 253355.

Single-chip fax modem. All the features of a fax modem are contained in the HD81900CPR1 from Hitachi. It satisfies relevant CCITT recommendations and needs only a 5V single-ended supply, consuming 350mW. Applications lie in Groups II and III and in low-speed facsimile transmission, also being used in add-on fax boxes connected to PCs via RS232. Hitachi Europe Ltd, 0628 585000.

CCD linear sensor. Reduction-type, high-sensitivity sensor from Sony, the ILX503, is meant for use in image scanners, fax machines and code readers. A single-side readout makes the DC difference zero and the 2048 pixel array enables documents up to B4 size to be read at a 400DPI resolution and at 5MHz. Timing generator and clock are on board and the units are compatible with 5V logic. Sony Components, 0784466660.

Oscillators

Crystal oscillator. Instead of the several ICs usually needed to produce a digitally compensated crystal oscillator, Murata's DC2200 series uses an asic. Stability is ±0.2 parts per million over -40 to 85°C, which is comparable with much larger and more power-hungry oven-controlled circuits (10W against the 50mW of these devices). Two types are on offer: a TTL-output oscillator covering 100kHz-22MHz and a cmos variety operating at 10MHz-25MHz. Murata Electronics (UK) Ltd, 0252 811666.

Programmable logic arrays

Field-programmable arrays. Expected later this year, Actel's ACT 3 field-programmable gate arrays (FPGAs) will contain up to 10000 gates, 16-bit counters running at 125MHz. Pin-to-gate ratio is said to be the highest available with over 200. Cmos 0.8micron technology is used, as is the Actel PLICE antifuse architecture. ACT 3 is one result of the technology and licensing agreeemnt between Actel and Hewlett-Packard. Actel Corporation, 081 839 3033

Synchronous PLD. A new BiCMOS PLD from Cypress Semiconductor, the CY7B333, is similar to the existing PAL22V10, but with higher density. Process is 0.8micron BiCMOS, with a clock-to-output time of 8ns, a combinatorial delay of 10ns and a set-up time of 8ns. There are 16 i/o macrocells in two banks of eight, each bank having separate clock inputs. Each macrocell has five programmable fuses to allow selection of function. Ambar Components Ltd, 0844 261144.

Fast 22V10 PLD. A 100MHz cmos 22V10-compatible programmable-logic device, the 85C22V10 from Intel, exhibits a 10ns propagation delay. Further, it consumes 40 less power than bipolar devices, which mean greater reliability and smaller power requirements. Design is aided by a new upgrade to the PLDshell software, PLDshell Plus, which is available free. Intel Corporation (UK) Ltd, 0793 696000.

Power semiconductors

Logic-level triacs. BT134W triacs from Philips are guaranteed to trigger with gate currents down to 5mA, and can be driven directly by cmos outputs. Combined with the elimination of special drive circuitry, the SOT-223 surface-mounted pack allows the use of the devices in a very small space. Trigger threshold for the BT134W is 5mA; that forthe BT134W-E, 10mA. Continuous current rating is 1A RMS, peak repetitive current 10A and surge 10A for 10ms. Devices in the range include some with blocking voltages of up to 600V. Philips Semiconductors, 071 436 4144.

PASSIVE

Miniature capacitors. Class 1 and 2 miniature ceramic-plate capacitors from Philips are claimed to have a failure rate of better than 5ppm. Class 1 types cover 0.47-560pF; class 2 0.47-47000pF at rated voltages of from 63V to 500V. Insulation resistance is up to 10,000MΩ. Gothic Crellon Ltd, 0734 788878.

Delay lines. Precision lines by Bishop Instruments are marketed here by Lyons. NDL types cover the range up to 5ns with a resolution of 2ps or 2.5ns and 1ps resolution up to 5GHz. PDL versions go up to 250ps at 0.1ps resolution and 0-7GHz bandwidth. Lyons Instruments Ltd, 0992 467161.

Feedthrough filters. Miniature filters designed with 1993 RFI standards in mind are introduced by Steatite. The range includes low series-inductance types in values from 1.5pF to 5nF, with resonant frequencies of over 200MHz. High-temperature components are also offered, working inthe range -55°C to 125°C. Steatite Insulations, 021 643 6888

Connectors and cabling

Socket and pin strips. The Cart range of strips from ODU come in 1 to 60 ways for high stacking density. Two pin cross sections are on offer, in one or two rows and in different grid spacings. The strips are also offered in customers' own configuration. ODU UK Ltd, 0653 600489.

Displays

Dot-matrix displays. Hewlett-Packard's aluminium gallium arsenide 5 by 8 alphanumeric displays with a character height of 58.4mm arenow supplied by Celdis. The HDSP-P10X/P15X series are expandable, XY stackable and have a wide viewing angle. -P10X types are diffused to give an even appearance to the light, with a loss of intensity, while the -P15X devices are less diffused for greater brightness. Power consumed by each dot is 36mW and current is 11mA average. Celdis, 0734 585171.

Hardware

Microstrip tuning. Standardised tuning tabs made from low-loss Ceramox ceramic by Oxley are for the matching of microwave devices to microstrip lines below 7.5GHz and over 13GHz. The DDT series is available with dielectric constants of 10, 100 and 160, with drifts of 10ppm/°C, -7 to +3, and ±20 respectively. Bulk resistivity of all three types is 60GΩmm. Oxley Development Company Ltd, 0229 52621.

RF shielding. Shapeo RF shielding, the Bradyshield, allows designers to concentrate shielding in small areas rather than to adopt the expensive approach of shielding an entire piece of equipment with metal or conductive paint. The shields are aluminium/polyester laminates, which are stable and bond easily to most surfaces. W H Brady Co. Ltd, 0295 271291.

Instrumentation

FFT analyser. Bruel & Kjaer's Type 2034 dual-channel FFT analyser has been reduced in price to £9400, which the company think will put it into the educational field. The instrument operates up to 25.6kHz, resolving down to 2mHz anywhere in the range. Control is menu-based, transducers are connected directly and generators are built into the instrument. Bruel & Kjaer (UK) Ltd, 081 954 2366.

Geiger-Muller counter. Offered in kit form, the K2645 counter from ECW gives an audible indication of radiation level and exhibits high sensitivity to gamma and high-energy beta rays. Battery life is more than two months continuous. Complete cunter kit with assembled board costs £92.24. ECW Instruments, 0376 517413

Transducer driver. SP300A is a stand-alone instrument generating a 112kHz signal to drive fast linear displacement transducers. Its 4 -digit display is scaleable to read a variety of units and transducers are available to measure displacements up to 150mm to within 0.1
. Aconditioned analogue output is provided for data loggers. Control Transducers, 0234 217704.

Function generator. Although primarily meant for the educational market, Wavetek's Model 19 2MHz sweep and function generator includes sine/triangle/square outputs, DC offset, variable symmetry and a log/linear sweep generator. An LCD display provides frequency, amplitude and offset information and further outputs give a cmos/TTL pulse and a 6V ramp following the sweep. Datron/Wavetek, 0603 404824.

L/C/Z meter. Keithley's new Model 3330 component tester measures inductance, capacitance, resistance, impedance magnitude (|Z|), Q, dissipation factor, ESR, conductance, reactance, phase, volatge and current. Test signals can be made low enough to test active devices. It is GPIB or front-panel programmable, sorts and bins and provides 0.1 basic accuracy from 40Hz to 100kHz. Keithley Instruments Ltd, 0734 575666.

RF millivoltmeter. Millivac's MV-1023A millivoltmeter measures volts, dBm and watts in the 10kHz-1.5GHz band of frequencies, ranges being 200µV to 300V, –60dBm to +63dBm and 1.8nW to 2W. The instrument is microprocessor-controlled and has, in addition to the four-digit led readout, a backlit LCD panel for messages on measurement instructions, staus and errors. The millivoltmetert is compatible with IEEE 488.2 and uses SCPI language for remote programming. Lyons Instruments Ltd, 0992 467161.

Electrostatic voltmeter. The Trek model 366 is claimed to be the world's fastest non-contact voltmeter, tracking voltages on any surface at frequencies up to 15kHz and at slew rates of up to 12V/µs. Its probe has two vibrating electrodes which are brought near to a charged surface, whereupon the electrode movement causes a voltage to be induced on them. Amplification and feedback nulls the PD between probe and surface, the required feedback voltage being a measure of the surface voltage. Range is ±2kV with ±0.05 resolution. Optilas Ltd, 0908 221123

Spectrum analyser. With a bandwidth of 9kHz-1.8GHz and careful front-panel design, the 2711 is

Balun transformers. These Toko transformers, which are either PCB or surface-mounted, come in three configurations: double-balanced mixer, distributor and directional coupler. They are bifilar wound to give good balance and the cores are selected for the 6-600MHz band, with some designs for 1.3GHz. Each type is available in a range of turns ratios. Cirkit Distribution Ltd, 0992 444111.

usable in a variety of fields by both experienced and new users. Sensitivity is -129dBm, there is 80dB of display range, spans down to 10kHz/division and selectable resolution bandwidth filters from 3kHz to 5MHz. There is a choice between true analogue display and digital storage, in which up to four runs can be compared. A menu offers carrier-to noise, occupied bandwidth, normalised bandwidth, signal search and FM deviation and one can store five antenna-correction tables. GPIB or RS-232C interfaces are available. Tektronix UK Ltd 0628 474799

RF power amplifier. Frequency range of the Wessex RC1002-20 broad-band amplifier is 800kHz to 1000MHz, minimum gain being 43dB, with a maximum variation of ±0.75dB. Output power is 20W minimum over the band. Power needs are 95-132V or 187-265V AC from 47 to 440Hz; a version using a DC supply is available. Wessex Electronics Ltd, 0272 571404

Interfaces

Sounder. A piezoelectric sounder, the AI-256K from Project Unlimited, is only 9.8mm high and takes 9mA at 12V to provide an output of 30dB at 30cm. A high-temperature version operates between -20°C and 100°C. Alan Butcher Components, 0258 840011.

Literature

Batteries. Standard and special batteries in lithium sulphur dioxide, lithium thionyl chloride, lithium polycarbonmonofluoride, alkaline manganese and zinc carbon technologies are detailed in a brochure from Crompton, whose products are chiefly intended for computer and marine use, as well as general electronics application. The company offers a free battery design service for special types. Crompton Eternacell Ltd, 091 456 1451

Monitoring and control. Led and LCD panel meters, printers, process monitors and calibrators are described in Datel's industrial monitoring and control handbook, which also includes a summary of the company's data acquisition boards, DC-to-DC converters and other data conversion equipment. Datel (UK) Ltd, 0256 469085.

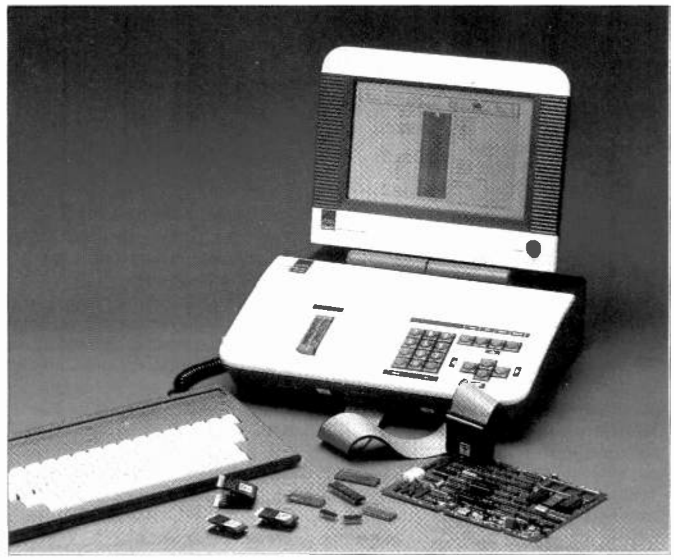
Ceramic components. Murata's new catalogue includes full technical descriptions of the complete range of EMI suppreion filters, microwave devices, sensors, piezoelectric buzzers and capacitors. Data sheets for each product are also available. Murata Electronics (UK) Ltd, 0252811666.

Instrument catalogue. Philips's new T&M catalogue covers a range of instruments from both Philips and Fluke. Among the new equipment described are the ScopeMeters, new standards equipment and some digital board-test instruments. Philips Test & Measurement, 0923 240511.

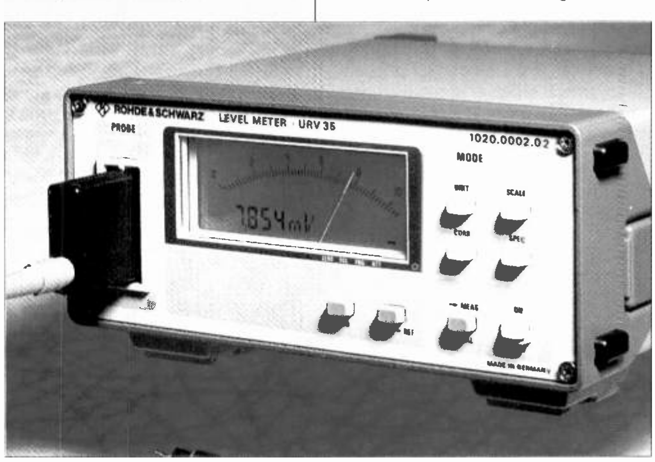
Metal-foil resistors. New catalogue from Alpha Electronics is concerned with very high-precision metal-foil resistors having a nominal temperature coefficient of 0.4ppm/°C. The components come in various forms, including face and wire-bonded chips, transfer-moulded and conformally coated types, networks, hermeticlly sealed and a new zero-TC type. Rhopoint Components Ltd, 0883 717988.

Production equipment

Short finder. ABI's Boardmaster 4000 board fault diagostic system now includes the facility to pinpoint short circuits on populated PCBs, instead of simply indicating that a short exists somewhere. Resistance between two shorted points is measured and displayed by bar graph, whose height is a measure of the resistance. Users of the Boardmaster 4000 or the DDS-40XP can upgrade to this new facility. ABI Electronics Ltd, 0226 350145.



Power/volt meter. Level Meter URV from R & S measures voltage and power to high precision and displays the result on both moving-coil meter and LCD, in the same panel aperture. The instrument is menu-controlled and, using a range of measuring heads, covers 100μV-1000V or 400pW-500mW from DC and 9kHz to 26.5GHz. Considerable shielding renders the readings invulnerable to interference even in the near field of antennas. Rohde & Schwarz UK Ltd, 0252 811377.



Materials

Metallised aluminium nitride. As an alternative to beryllia, aluminium nitride possesses several advantages, among which is its environmental safety. Oxley have now perfected a method of chemical bonding metallisation patterns to the substrate — previously a problem. The material has high thermal conductivity, low dielectric constant and high insulation resistance. It also has a coefficient of thermal expansion that closely matches that of silicon, a property that reduces stress with power dissipation; with its other properties it is therefore well suited to power semiconductor and multi-chip applications. Oxley Development Company Ltd, 0229 52621.

Magnet chargers. Trilec capacitor discharge magnet chargers from Omitec provide up to 28,000 joules magnetising energy in the formof current pulses. A digital indication of pulse voltage and current is provided and a "low-pulse" indicator gives a warning if the pulse falls below a preset level. Also in the range are computer-controlled magnet processors, in which software is written to suit the application and to give a staistical analysis of production and reject levels. Omitec Instrumentation Ltd, 0380 729256.

Stereo inspection. VS7 stereo scanning inspection system from Vision Engineering allows the user to examine devices with pitches down to 4mil for solder quality and joint soundness. VS7 provides a colour, high-resolution stereo display of the component without the use of a binocular eyepiece. System magnification is 60 times direct and 40 times oblique, with a working distance of 28mm. Vision Engineering Ltd, 0483 223417.

Power supplies

Switchers. Tamura Hinchley's FEM series of switched-mode power supplies now come in 30W versions, which can be connected to any supply from 85 to 265V AC at 50Hz or 60Hz. Outputs are ±5V and ±12V; ±5V and ±15V; ±5V and 12V. Power trading between outputs is available on all models. A 50W version, the FEM-50, is also available. Safety Power Group, 0932 336025.

Mosfet switcher. With a power-factor correction of more than 0.99, the HC1010 switching power supply from HC Power provides 1000W at a THD of less than 5 – in line with the European IEC555-2 standard. Input range is 90-264V AC with limited inrush current. MTBF is 250,000 hours minimum. XP plc, 0734 845515.

Radio communications products

RF & microwave couplers. A range of couplers including 3dB coaxial hybrids, directional and dual directional and 3dB card couplers is announced by European Microwave Components. 3dB card couplers cover 30MHz-6.4GHz, handling 50-100W, while the coaxial couplers allow 3,6,10,20 and 30dB coupling up to 14.5GHz at 2-50W. European Microwave Components, 0376 515200.

RF modules. A number of "Cell Packs" from Toshiba are available. These are HF circuits in modular form, consisting of amplifiers for narrow and wide band working, mixers and oscillators for operation at up to 2.5GHz and 28dB gain. SOT-23-sized packs are used. Toshiba Electronics (UK) Ltd, 0276 694600.

Miniature UHF transceiver. A UHF radio transceiver for use in portable data capture units, the TCV450, has a 10ms T/R switch for rapid data exchange when taking data from intelligent outstations. Receive current is less than 15mA and it puts out either 500mW or an adjustable low power of 1-50mW for battery economy. To improve T/Rswitching time further, a "hot standby" mode allows the transmitter to be enabled in less than 1ms. Operating band is 400-470MHz, with 25,20 and 12.5kHz spacing. Wood and Douglas, 0734 811444.

Switches and relays

Sealed miniature switches. Very small toggle switches from Caro are claimed to be proof against dust and water. Units in the 200 series are designed for PCB mounting and come in 3 or 6-pole versions, with five different functions, with either metal or plastic levers and in five terminal arrangements. They are rated at 0.4VA with voltages of 28mV-28V and insulation resistance is 500V DC at 1000MΩ. P Caro & Associates Ltd, 021 7421328.

Transducers and sensors

Rotary sensor. Contactless rotary sensors in the Bluepot range by Midori have an electrical function angle of ±45° at an output sensitivity of 1.5 of the input (12V DC) per 10° rotation. Independent linearity is ±2 of full scale and the input impedance is 12kΩ ±30. Kynmore Engineering Co. Ltd, 071 405 6060

Piezo positioners. NTK, a Japanese company, have introduced a range of piezoelectric actuators for fast-response, large displacements. The devices use the piezoceramic bimorph principle in reverse, so that applying a voltage causes a deformation. Position control to a resolution of 0.01µm is obtainable in a feedback circuit. Piezostack modules contain a number of the elements which can provide a constant high pressure outside the range of solenoids. Quantelec Ltd, 0993 776488.

COMPUTER

Computer board level products

Input scanner. As an alternative to annunciator panels, the ISI64 scanner is an interface to Amplicon's message displays and allows 64 single-contact inputs to call programmed fault, alarm or instruction messages. Master/slave operation allows up to 256 inputs and the unit will work with alphanumeric message panels, with AC or DC power supplies. Amplicon Liveline Ltd, 0273 608331.

96-channel i/o. An extension to the Blue Chip range of programmable i/o cards is the PIO-96, a general-purpose interface card having 96 digital lines that can be programmed as inputs, outputs or a combination. Signals in and out are at TTL levels. 50-way IDC connectors terminate the 96 i/o and two common lines and allow a screw-terminal block to be attached. The board works with PC XT/ATand the true look-alikes. Blue Chip Technology, 0244 520222.

60Mflops with analogue i/o. DBI96 from Data Beta is a PC extension card for video and audio processing providing 60Mflops of peak processing power and 16-bit analogue i/o, together with 64Mbyte of dram. It uses the Motorola DSP96002 signal processor and the extensively expandable Hyperbus mezzanine bus for communication between boards without overloading the PC. DT-Connect, for the support of co-processors, custom i/o and access to frame-grabber outputs is also included. The BUG-96 code debugger is supplied and an option is development software including SPOX operating system and a C compiler. Data Beta Ltd, 0734 303631.

Four-channel analogue input. Datel's PC-414A analogue input board samples four channels simultaneously by means of four sample-and-hold amplifiers, multiplexed to a 1.5MHz, 12-bit A-to-D converter. It is intended for phased sonar arrays, receiver correlation and de-skewing of multiple signals. Data is continuously streamed, with no loss, to PC AT memory, via an on-board 4K Fifo register. A parallel port allows the board to be used as a front end for array processors or other systems. Datel (UK) Ltd, 0256 469085.

AT processor card. A half-length AT-compatible processor card, the SC-286 from Fairchild, plugs into a standard AT passive backplane to give the functions of a 16MHz motherboard, two serial ports, a printer port, floppy interface, IDE hard-disk interface and keyboard connector. Lack of sensitivity to noisy surroundings and a built-in watchdog timer that resets the CPU if the system hangs means an easy mind if the unit is used in critical or unattended conditions. The card is available in one of a range of PC chassis or as an OEM component. Fairchild Ltd, 0703 559090.

DSP on a PC. EPC166 from Hitex is a co-processor card for the PC,which turns the computer into a real-time data acquisition and processing instrument. Using the Siemens RISC 80C166 microcontroller, the combination provides 12-channel A-to-D, 64 digital i/o lines, 16 PWMs, 16 capture and compare channels, two uarts, 256Kb static ram, a digital PLL and 10MIPs at 40MHz — all making the system very suitable for DSP or complex real-time process control. Programming is in either C or assembler. Hitex (UK) Ltd, 0203 692066.

Faster neural nets in Windows. A plug-in accelerator card for PC ATs and the like gives more than 100 times increase in the speed of the Neural Desk neural network package running in Windows 3 The speed increase comes from an ability to speed up the training procedure, but the card also improves the performance and response time of installed programs; it will go into any expansion slot. Neural Computer Sciences, 0703 667775

Industrial i/o. To interface bus-based and single-board microcomputers to the world of industrial wiring, RXI01 by Syntel is a 16-channel module having eight digital outputs to switch up to 30V DC at 2A and eight digital inputs reading from 12 to 24V DC. I/o lines are opto-isolated to 2.5kV and and are reverse-polarity protected, leds indicating their status. De-bouncing is incorporated for each input. Syntel Microsystems, 0484 535101.

Development and evaluation

H8/330 evaluation board. Hitachi now have the LEV8330, which is an evaluation board for the H8/330 family of microcomputers. This s a single board, with built-in firmware to provide monitoring and debugging, which works with a PC via the supplied serial interface and software. It contains PIAs and uarts to replace i/o used by the system. Hitachi Europe Ltd, 0628 585000.

16-way gang programmer. Up to 16 memory cards may be programmed by this device, which is intended to copy data for distribution to point-of-sale terminals, for example. It is available as a stand-alone instrument or as an extension to the ITT Cannon PCMEM PC-based memory card development system, in which the programmer enables DOS file transfer and editing to be used to customise each card in the unit. A novel copying procedure makes for high-speed copying. ITT Cannon, 0256 473171.

Computer peripherals

Rewritable optical disk drive. Optistore 650 is claimed by DPL tobe the fastest in the world, having an access time of 37ms. It uses 5.25in disks and has a formatted capacity of 652Mbyte, supported by a 256Kbyte buffer. The unit will interface to a range of host computers, including Apple Mac, Sun and the IBM PC and supports synchronous or asynchronous SCSI transfer at 4Mbyte/s and 2Mbyte/s respectively. Data Peripherals (UK) Ltd, 0785 57050.

SCSI interface. Rimfire 5500 is a SCSI peripheral interface for transparent integration into PC AT systems. It possesses its own 80186 processor, performing DMA transfers at up to 10Mbyte/s. An on-board BIOS eprom allows the system to be booted from SCSI disks, configuration changes being performed by means of standard software. Unix, Netware, OS/2 and MSDOS SCSI subsystem software avoids the need for operating-system changes. AT floppy-disk drives are supported, as are SCSI-2 devices. Diamond Point Intl Ltd, 0634 722390. ■

Teletext de-chaffer. MicroEye TV1 from Digithurst goes between a teletext source — a television — and a PC, with a view to sorting the selected wheat from the broadcast chaff. The software that comes with the card looks through the received pages and alerts the user when some of the wheat is found, importing it into Windows for formatting and subsequent printing. To further relieve the user of possible fatigue, the unit will learn the codes used by a video recorder's handset and use them via its own handset to switch the video on when something of interest appears. Digithurst Ltd, 0763 242955.

Oscillating between decametric and millimetric waves

Oscillators, even in this digital era, remain at the heart of RF electronics. Novel ideas, new active devices for an ever-wider frequency range and the adoption of quasi-optical techniques akin to those of the gas laser all continue to merit attention. So it was surprising that only 30 people attended the IEE colloquium "Characterisation of oscillators - design and measurement" – particularly as the papers reported important new developments in oscillators. Devices spanned 5MHz to 100GHz, ranged in output powers from a few milliwatts to a few kilowatts, and covered everything from vacuum tubes to heterojunction bipolar transistors (HBT), animal tagging devices to industrial RF heaters.

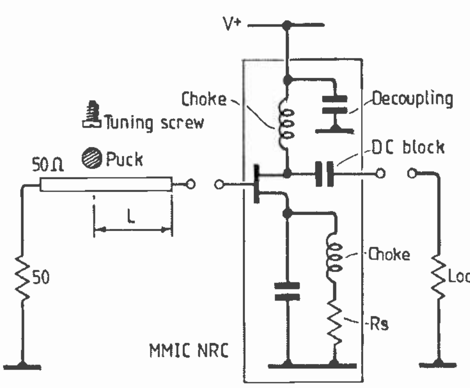
Better DDS

RF continuous-wave oscillators are inherently analogue devices. But significant progress is being made in reducing the phase noise of direct digital synthesisers (DDS). As costs steadily reduce and more suitable devices appear, DDSs seem set to replace phase-locked-loop synthesisers for many of the more demanding applications in communications and radar.

M Bozic (University of Bradford) who, with Professor JG Gardiner, has been carrying our work sponsored by GEC Plessey Semiconductors, has achieved excellent phase noise characteristics with DDS using 100MHz ECL. His synthesiser has a close-to-carrier phase noise profile comparable to the very best non-synthesised oscillators: –120dBc/Hz at 10Hz offset from a 5.85MHz carrier.

Phase noise performance is of paramount interest in such critical areas as Doppler radar. Also, output from a DDS often needs frequency translation to microwave frequencies through use of direct analogue synthesisers or phase locked loops, so phase noise characteristics of devices need to be accurately determined.

Bozic has found that DDS used with the correct clock source produces a close-to-carrier phase noise profile comparable to free running oscillators and so is suitable for demanding applications. Phase noise floor will depend largely on the logic family and the specific properties of the D-to-A converter. Bozic's measured results show a relationship between the phase noise profile of the synthesised waveform and the phase noise profile of the clock source.



AW Dearn reported an RF-on-wafer MMIC-based dielectric resonator oscillator within a single-chip low-noise downconverter (LNC). Prototype chips have an IF output between 0.95 to 1.3GHz.

Consumer electronics

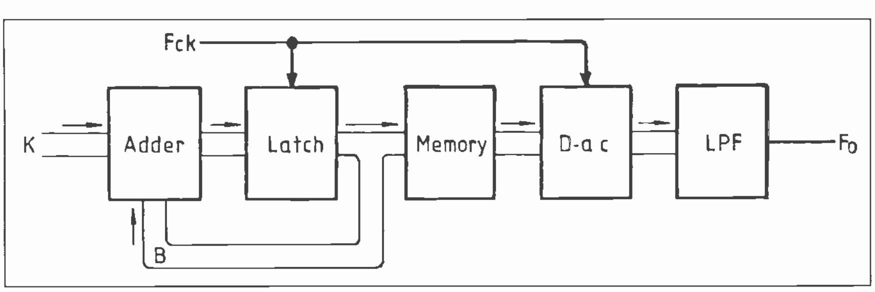
An interesting consumer electronics development was reported by AW Dearn (GEC-Marconi Materials Technology Ltd, Caswell) in a project partly funded under the Espirit 5018 Cosmic programme. He described an RF-on-wafer (RFOW) MMIC-based dielectric resonator oscillator (DRO) within a single-chip low-noise down-converter (LNC). The device is said to be suitable for reception of DBS signals between 10 and 11.5GHz (noise figure about 1.2dB) and prototype chips have an IF output between 0.95 to 1.3GHz.

A single negative-resistance circuit (NRC) included on chip allows use with an externally-stabilised dielectric resonator (puck and tuning screw). To cover the full range from 10 to 11.5GHz DR pucks for 10.8GHz are used. In a novel feature, test pads are included on all three ports. The facility makes possible RFOW testing of the LNC – a highly desirable facility from a cost viewpoint since it allows pre-selection of RF-good devices before dicing, sorting, package assembly and bonding.

Peter Topham (GEC-Marconi Materials Technology) together with Dearn and G Parkinson reported on use of the GaAs heterojuction bipolar transistor (HBT) as a low-phase-noise oscillator of wide tuning range. Frequencies range up to 20GHz and the device includes, for the first time, a yig-tuned HBT oscillator. The work has underlined the phase-noise advantages of HBT's compared with mesfet devices and also breaks new ground in several ways.

Topham reported the widest electronic tuning range yet achieved for an HBT oscillator (1.8 to 1), and by using a yig-resonator as the tuning element, said he has achieved the lowest phase noise so far reported for a variable-frequency HBT oscillator (–110dBc/Hz at 100kHz offset). The varactor-tuned oscillators achieve a tuning range of 1.3 to 1 and phase noise of –100dBc/Hz at 100kHz offset – comparing favourably with silicon BJT oscillators and some 25-30dB quieter than GaAs mesfet oscillators.

All this makes the HBT an attractive device for microwave sources at higher frequencies. By taking advantage of the semi-insulating substrate, monolithic



Building blocks of the direct digital synthesizer.

DDS design

A DDS comprises four main components: a phase accumulator; a phase-to-amplitude converter; a digital-to-analogue converter; and a low-pass filter (LPF). The phase accumulator counts through the memory look-up table storing a digitised sine wave at a rate proportional to the required frequency setting. The memory converts the phase information into amplitude information as a N-bit approximation of a sine wave. The DAC translates this into staircase form. The LPF removes unwanted high-frequency sampling components.

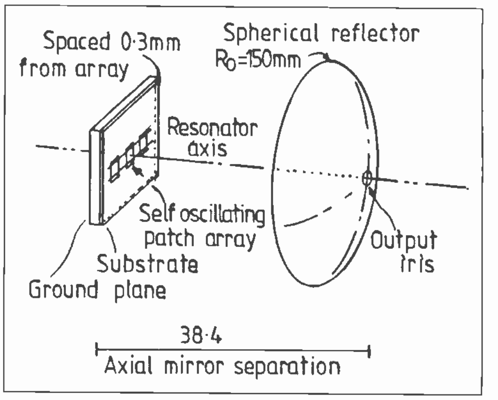
integration of complete oscillators should be possible.

Still more to learn

Turning to valves, it might be thought that during the past eighty years, designers would have discovered all they need to know about power oscillators based on this well-established technology. But P M Sawyer (EEV) reports he has been achieving more consistent power efficiency than normally found in industrial RF heaters used on the lower-frequency ISM bands. Working with a *BR1162* valve in a 10MHz grounded-grid high-power oscillator, he has shown that the high efficiency extends to a wide frequency range and depends critically on feedback impedance. The usual fall off in efficiency at lower frequencies arises from the effect of the phase angle on the anode voltage swing. To avoid a significant reduction in efficiency, the reactive impedance in the input circuit needs to be low compared with the resistive impedance.

P G Frayne (Royal Holloway & Bedford College) was one of several speakers describing work connected with quasi-optical millimetre-wave oscillators. He noted that at these frequencies it is possible to construct an oscillator very similar in principle to the gas laser, though with some essential differences: amplification is through a surface rather than a volume distribution of negative resistance; and frequency is determined by natural frequency of the gain element and the resonance condition for the Gaussian beam mode excited within the quasi-optical cavity. Frayne's work includes a self-oscillating CW power-combiner achieving near 100% efficiency with small numbers of printed microstrip Gunn-diode sources.

Pat Hawker



G Frayne described construction of an oscillator very similar in principle to the gas laser.

Lower power tagging

Electronic tagging applications need a reduction in drain on the battery. G B Morgan (University of Wales) reported work carried out by KF Tsang (City Polytechnic of Hong Kong) on high-efficiency 800MHz oscillators based on an improved version of the procedure developed in Poland by Marian Kazimierczuk. An output power of 26dBm with an efficiency of better than 54% and a noise of –80dBc/Hz at 10kHz offset has been achieved, with stability relatively insensitive to collector-voltage variations – though careful measurement is required on individual transistors used.

Ian J Dilworth (university of Essex) has also been working to reduce power consumption of sub-miniature VHF crystal-controlled animal and fish tracking devices, but by pulsing the oscillator rather than increasing inherent efficiency. For this application he showed that conventional third overtone AT-cut crystals, despite the need for frequency multipliers, tend to prove superior to the newer chemically-etched VHF crystals which have a higher average ESR.

Oscillators and multipliers providing a few milliwatts of power output at spot frequencies in the range 200-800MHz have been developed with surface-mount components and are capable of operating down to a 1V supply. The most efficient power source is a zinc-air battery, but this cannot be used for fish tagging (such as salmon in fresh water) and a silver-oxide battery is used instead. ■

TEL 081 652 8339 **FAX 081 652 8931**

APPOINTMENTS

Design Engineers

Celertec is an electronics design consultancy, within a PLC group, specialising in innovative radio data communication projects.

To find real solutions to novel problems, we are currently seeking two bright creative design engineers, with several of these skills:

- VHF or UHF radio
- Analogue and digital logic
- Microcontroller and HLL software
- Custom chip design
- Use of electronics CAD tools

Graduates with 4 years' experience are ideal but innovators with more or less experience should apply too. Starting salaries will match experience and qualifications.

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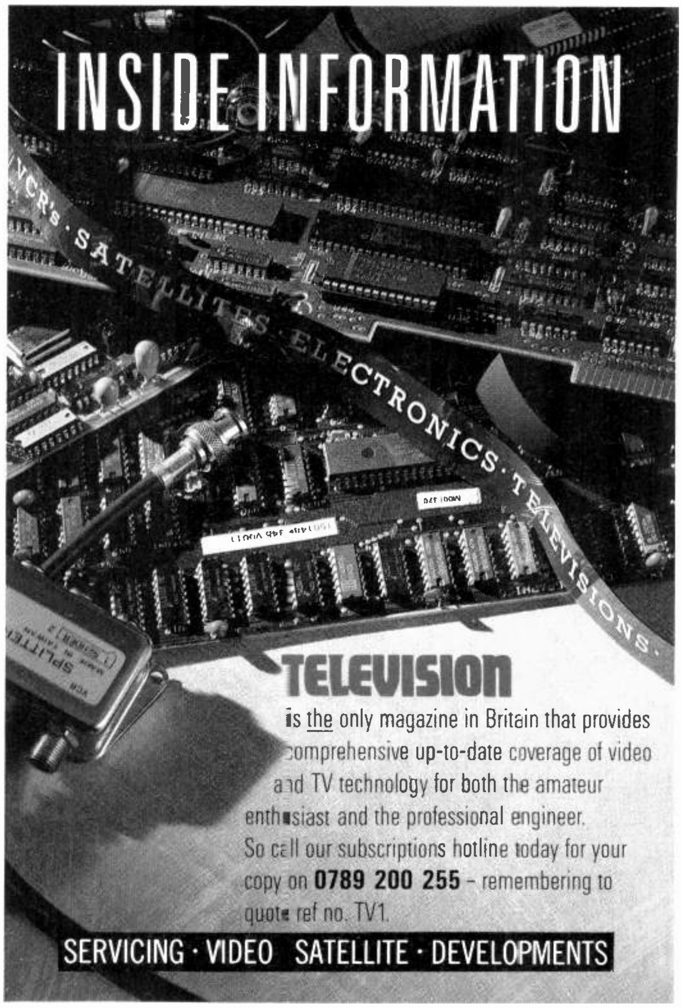

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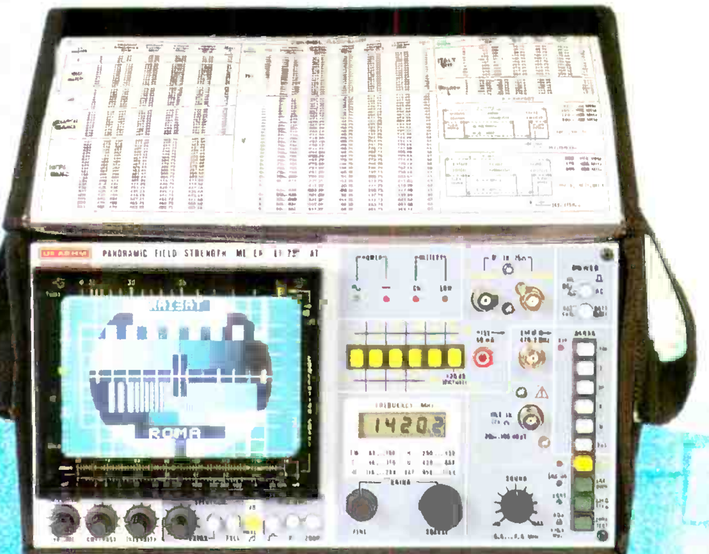

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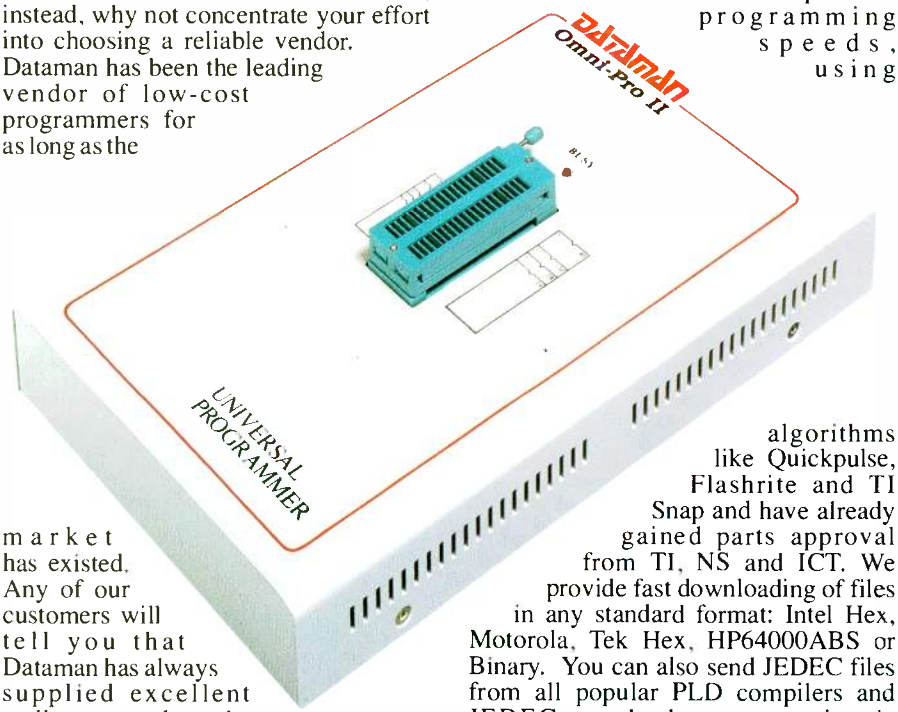

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