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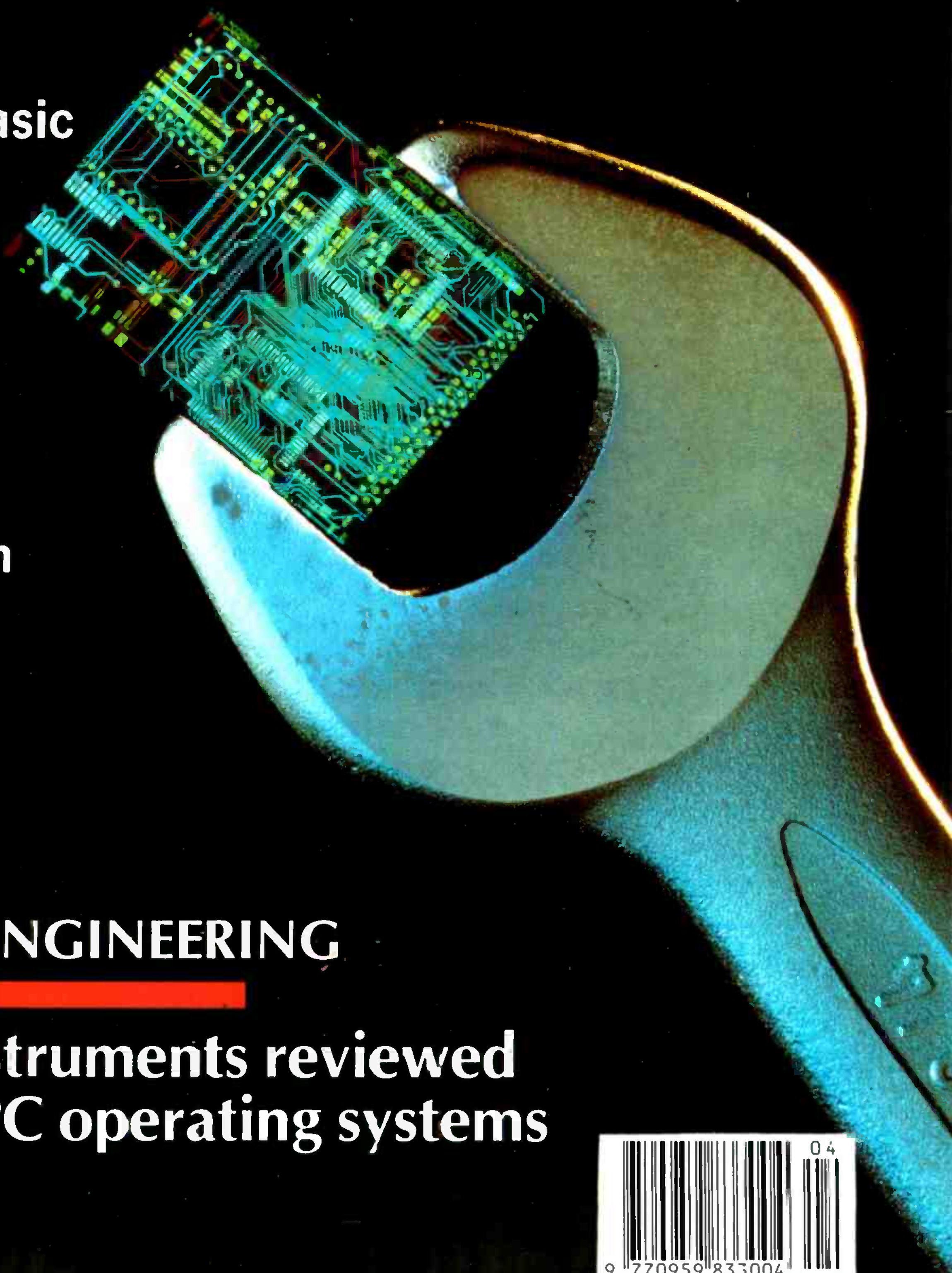

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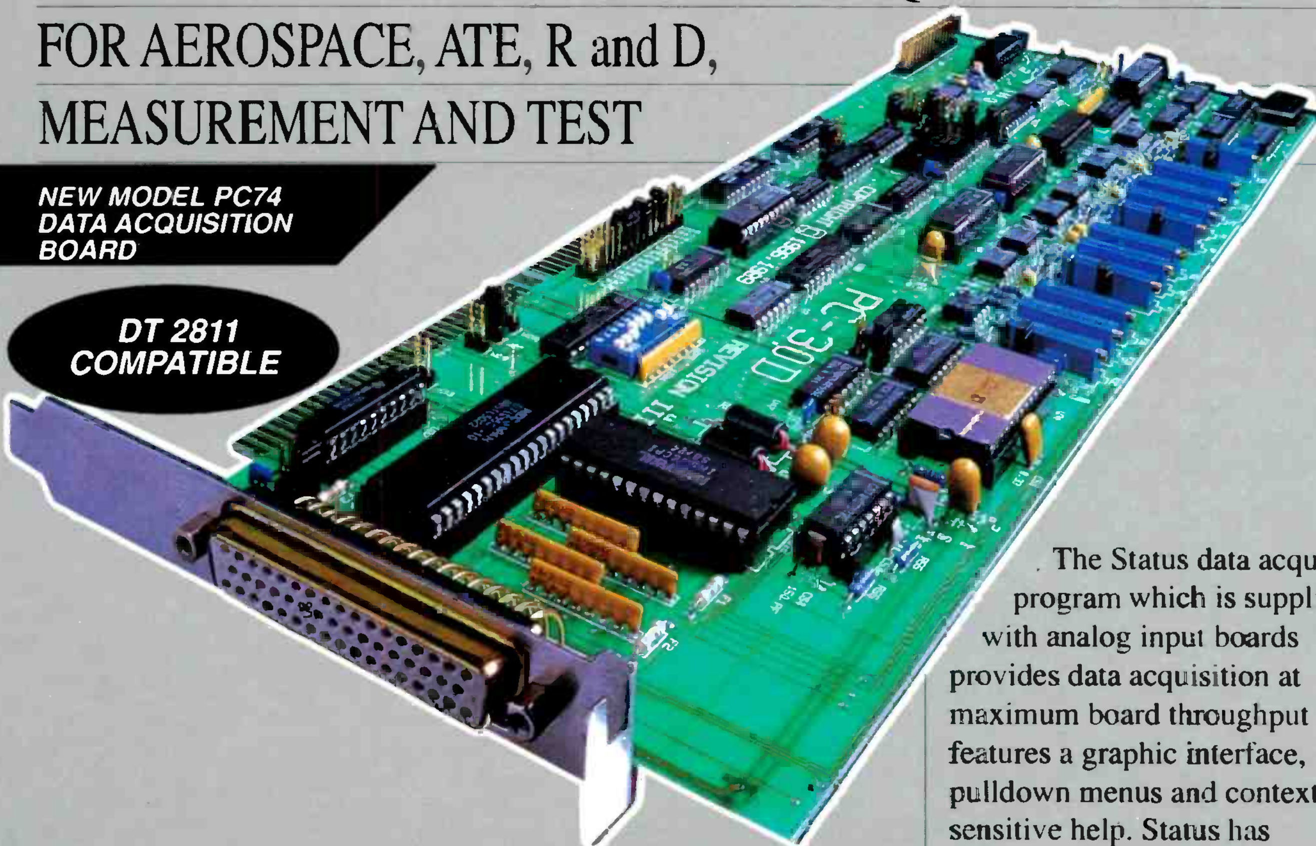

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PC-30	25KHz	12	16 i/ps	----	2	2	-	NO	24 lines	No
PC-30B	30KHz	12	16 i/ps	----	2	2	-	YES	24 lines	No
PC-30C	100KHz	12	16 i/ps	----	2	2	-	YES	24 lines	No
PC-30D	200KHz	12	16 i/ps	----	2	2	-	YES	24 lines	No
* PC-30DS	200KHz	12	16 i/ps	----	2	2	-	YES	24 lines	No
** PC-30DS/4	200KHz	12	16 i/ps	----	2	2	-	YES	24 lines	No
PC-30PGL	**200KHz**	**12**	**16 i/ps**	**8 i/ps**	**2**	**2**	**-**	**YES**	**24 lines**	**1, 10, 100, 1000**
PC-30PGH	**200KHz**	**12**	**16 i/ps**	**8 i/ps**	**2**	**2**	**-**	**YES**	**24 lines**	**1, 2, 4, 8**
PC-26	25KHz	12	16 i/ps	----	-	-	-	NO	No	No
PC-74HA	30KHz	12	16 i/ps	8 i/ps	2	-	-	NO	16 lines	1, 2, 4, 8
PC-74LA	30KHz	12	16 i/ps	8 i/ps	2	-	-	NO	16 lines	1, 10, 100, 500
PC-74HC	80KHz	12	16 i/ps	8 i/ps	2	-	-	YES	16 lines	1, 2, 4, 8
PC-74LC	80KHz	12	16 i/ps	8 i/ps	2	-	-	YES	16 lines	1, 10, 100, 500
PC-32/H	2,5KHz	16	16 i/ps	8 i/ps	-	-	1	NO	No	1, 2, 4, 8
PC-32/L	2,5KHz	16	16 i/ps	8 i/ps	-	-	1	NO	No	1, 10, 100, 500
PC-33/H	2,5KHz	16	16 i/ps	8 i/ps	-	-	-	NO	No	1, 2, 4, 8
PC-33/L	2,5KHz	16	16 i/ps	8 i/ps	-	-	-	NO	No	1, 10, 100, 500
PC-34	-----	--	----	----	-	-	1	NO	No	---
PC-66	-----	--	----	----	12	-	-	NO	No	---
PC-66A	-----	--	----	----	8	-	-	NO	No	---

* Has 16 simultaneously sampled inputs
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CONTENTS

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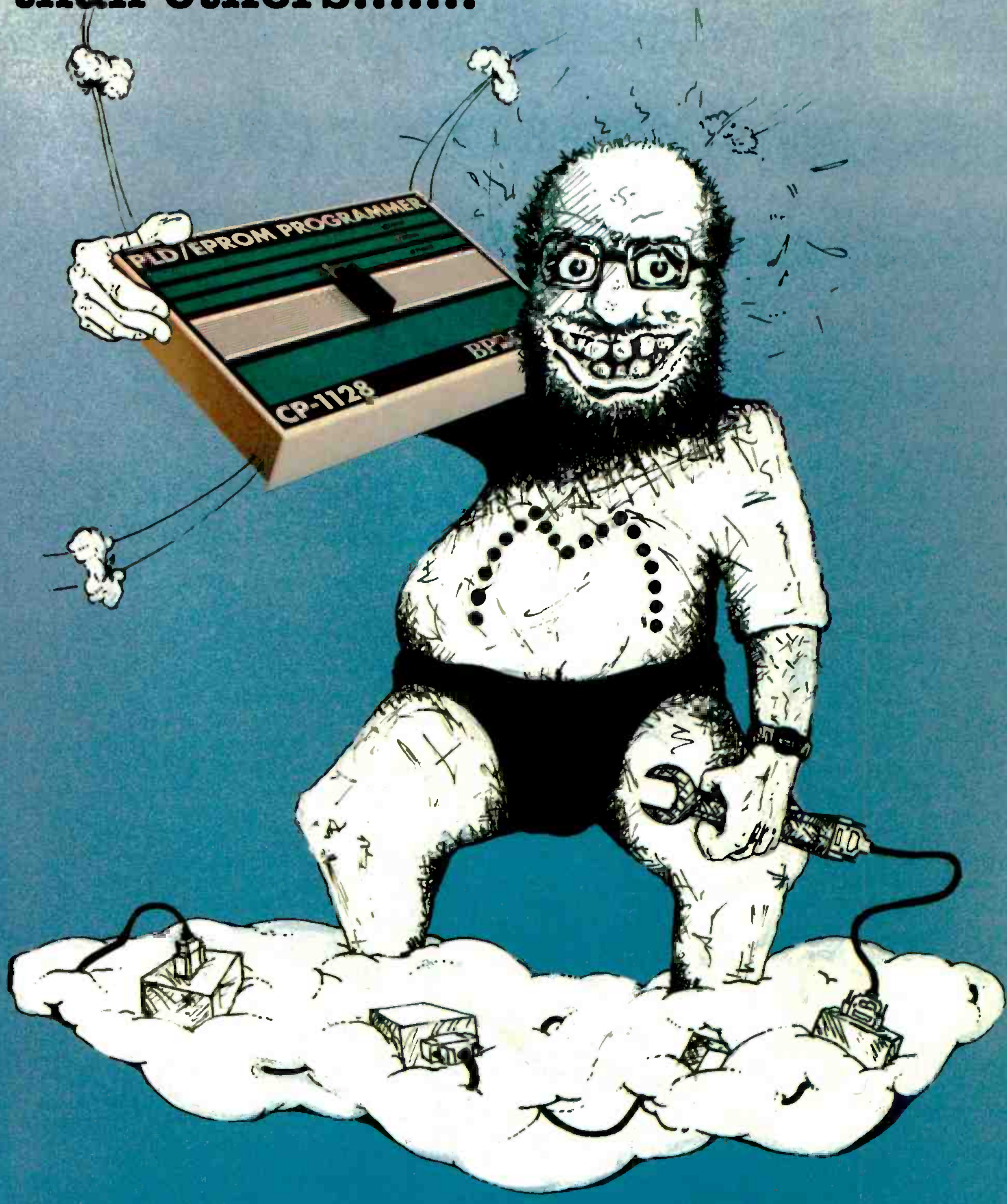
REGULARS

In next month's issue. As yet only the military superpowers have made use of Over-The-Horizon-Radar. The Australians are now planning to spend nearly £400 million on an HF radar system to protect their sparsely populated northern coastlines.

The impetus behind the radiating monster is civilian; the Australian government hopes to use the radar to detect illegal aircraft running drugs into the Northern Territories. However, the massive pulsed HF power spells bad news for communications systems operating around 14MHz.

Some programmers are more powerful than others.......



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Researching priorities

The Science and Engineering Research Council has recently been involved in the yearly flurry of indignation over underfunding allegations. In essence, SERC is faced with effective budget cuts of up to £30 million which temporarily placed the Daresbury Nuclear Structure Facility under threat of closure. The Daresbury NSF provides a synchrotron source for UK particle physicists.

Ramifications of the argument include an alleged overcommitment by SERC to international big science projects, principally CERN at Geneva, which have experienced greater cost inflation than SERC's UK commitments. Because Britain's percentage contribution is fixed by international agreement, the effect has been to reduce differentially the funds available for UK work.

It seems sensible to bring into question the entire system of UK science funding. After all, we would expect other areas of the economy to be subject to performance tests. Why not science? The fundamental question is this: is pure science a luxury or a necessity?

The Japanese funded their economic miracle by investment in applied science. Their electronics industry took over the world by concentrating on research into the humdrum. It didn't question string theories, it couldn't care less about the precision of the statement "$e=mc^2$". It concentrated on materials research, artificial intelligence on the production line, the movement of atoms around a semiconductor lattice. This resulted directly in ceramic exhaust valves for vehicle engines, uniquely efficient industrial production, hegemony in advanced semiconductor supplies.

One could argue that any of these achievements is more worthy than the detecting of a neutrino, the analysis of radiation from a black hole or the knowledge that things aren't quite what they seem at the speed of light.

Neither can it be taken for granted that big science generates useful spin-offs with cost effectiveness. Although the Apollo programme resulted in non-stick frying pans, it might be said that a down-to-Earth related space programme costing the same amount of money could have resulted in earth resources technology plus non-stick frying pans. In short, the sponsoring of competent research into the tangible problems of industry seems more likely to produce useful spin-offs than indulgence in pure science.

What is the Western preoccupation with high science really about? While few of us would disagree that the reciprocity between the light-years of cosmology and the femtoseconds of subatomic particle physics is truly a source of wonder, it shouldn't be an aspect of ersatz religion which, one suspects, big science has become.

The size of a science research budget should be commensurate with the generally perceived value of the aim. After all, the really useful things in life don't require obscure explanations of their worth.

Frank Ogden

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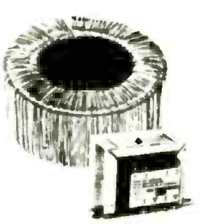
Toroidal Transformers



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Toroidal Price List

Quantity prices Exclude VAT & carriage

VA	Mail Order	Quantity Price Excluding VAT & Carriage 2+	10+	25+	10+	100+
15	12.16	8.51	6.89	5.17	5.02	4.87
30	13.37	9.36	7.35	5.68	5.51	5.35
50	14.86	10.40	8.17	6.32	6.13	5.94
60	15.02	10.51	8.26	6.38	6.20	6.01
80	14.98	10.50	8.25	6.38	6.19	6.00
100	17.58	12.29	9.88	7.48	7.24	7.02
120	17.95	12.57	9.87	7.63	7.41	7.18
150	21.65	15.16	11.81	9.20	8.93	8.66
160	19.86	13.90	10.92	8.44	8.19	7.94
225	25.09	17.56	13.80	10.66	10.35	10.04
300	28.60	20.02	15.73	12.16	11.80	11.44
400	38.49	26.94	21.17	16.36	15.88	15.40
500	42.07	29.45	23.14	17.88	17.35	16.83
625	44.24	34.47	27.08	20.93	19.31	18.70
750	48.66	38.86	28.98	22.38	21.72	21.06
1000	65.67	45.97	36.12	27.91	27.09	26.27
1200	68.71	48.10	37.78	29.20	28.34	27.48
1500	87.58	61.36	48.17	37.22	36.13	35.03
2000	114.45	80.11	62.95	48.64	47.21	45.78
2500	135.87	95.11	74.73	57.71	58.04	54.35

These prices are for single primary with two equal secondaries with 8" colour coded fly leads. Each transformer is supplied with a mounting kit, consisting of one steel washer, two neoprene pads, and a nut and bolt.

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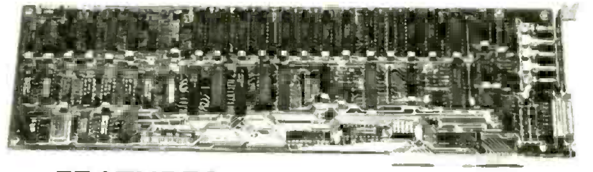
PC WAVEFORM GENERATOR



FEATURES

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Is lumpy universe theory half-baked ?

The scale of the Universe is so mind-bogglingly big that it's scarcely surprising when cosmologists have to tinker around with theories to accommodate the vast wealth of information being beamed down from the various orbiting observatories. But to judge from a recent paper (*Nature* vol. 349, no 6304) by British and Canadian researchers, some of theories are so seriously adrift that it's virtually back to the drawing board.

What is in particular trouble is the notion of cold dark matter (CDM), a concept put forward to explain the lumpy distribution of matter in the universe. CDM, or something like it, was introduced because cosmologists could not otherwise understand how galaxies managed to form so quickly from what was originally a very smooth, homogenous beginning — we know it was smooth because echoes of Big Bang can still be detected in the form of an isotropic 3K microwave background radiation.

CDM, consisting of slow moving ghostly particles, has never been detected, but if it were to make up about 90% of the Universe, it could have drawn matter together into the lumpy structure we observe today. The presence of CDM would also satisfy other cosmological problems for which a large amount of matter is a prerequisite.

Hot or faster moving particles might supply some of the "missing" mass, but they don't stay in one place for long enough to explain the clustering of the galaxies.

Cold dark matter seems to explain so well virtually every feature of the universe that it is often taken for granted. Small wonder, then, that the latest study questioning its validity has caused quite a stir.

Using data from the infra red astronomy satellite Iras, the cosmologists have mapped the locations of 2000 individual galaxies and showed that, on a scale of hundreds of millions of light years, the Universe is just much too lumpy. Clusters of galaxies are lumped together into huge blobs and filaments with relatively empty voids in between.

Professor Michael Rowan-Robinson of Queen Mary and Westfield Colleges in London, one of the study's authors, says that CDM theory can explain mass distribution up to the size of the Virgo cluster

Supercool scientists take the heat out of fast chips

Chill a container of water below 0°C and it will gradually freeze into a block of ice. But use a very pure liquid — and take great care — and the temperature can be lowered below its normal freezing point without any ice crystals appearing. Researchers are now wondering if this phenomenon could be harnessed in cooling superfast and high density chips.

"Supercooled" fluids are highly unstable and will freeze suddenly if disturbed by any noise or movement. But Dr David Awschalom of IBM's Thomas J Watson Research Centre, Yorktown Heights NY has shown that, in a container only a few tens of molecules wide, many liquids can be supercooled to well below their normal freezing points and can spend weeks in this remarkably stable liquid state.

In one series of experiments Dr Awschalom and his team found that liquids trapped in tiny containers could be chilled to 40% below their normal Kelvin freezing points without solidifying. As the size of the container decreased, the freezing point progressively dropped, an effect Awschalom calls "geometric supercooling".

The containers used in the experiments are interesting because they are not, as might be expected, tiny glass test-tubes, but microscopic pores in blocks of special high-porosity glass.

Size of the pores is controlled during the manufacturing process; they are then filled with a variety of experimental fluids, including liquid oxygen, liquid nitrogen, alcohol, carbon disulphide and nitrobenzene.

But depressed freezing points are not the only peculiarities of geometrically supercooled fluids. Using a glass block containing tens of thousands of pores, Awschalom has discovered some unusual acoustic properties.

Ultrasonic techniques to measure the velocity and attenuation of sound waves show that although they are physically liquid, geometric supercooled fluids can have similar acoustic behaviour to solids; sound waves travel faster and experience less damping. This discovery could be of crucial importance for oil exploration where prospectors use sound waves to try to distinguish pockets of oil from rock. Awschalom thinks that supercooled oil in porous rock in arctic regions could well be masquerading as solid rock. If that is true then exploration teams could be missing a lot of good deposits.

Of course that possibility is pure speculation, but there are several more down-to-earth applications for geometric supercooled fluids. One that is particularly exciting is the prospect of their use for cooling high speed chips.

As things stand, the ability to dissipate heat is probably the biggest barrier to increasing switching speed and/or processing density. As chip structures shrink and processing capacities rise, there is an ever-increasing risk of overheating.

If molecule-sized channels were to be machined into the structure of a chip, supercooled fluids could be pumped through them to remove the surplus heat. It is a process that should be aided not only by the lower temperature of the fluids, but by another strange physical property that occurs at very low temperatures, superfluidity. Superfluidity — the loss of viscosity — is also affected by the size of the container in which a fluid is confined, a subject currently under investigation.

David Awschalom believes that all these fascinating properties of supercooled liquids could eventually have widespread applications, not just in computers and oil prospecting, but in cooling and lubricating tiny gears and motors smaller than the eye can see.

of galaxies. But cold dark matter cannot be reconciled with the structure of superclusters.

He admits that most cosmologists probably do not now know in which direction to go in terms of new theories.

Rowan-Robinson himself believes that it might be possible to create a cosmological model involving both cold dark matter and hot dark matter, the hot material consisting of particles like neutrinos travelling at near to the speed of light.

Another possibility that would save the CDM theory would be to resurrect a concept invented by Einstein in 1917 and later disowned. Einstein's cosmological constant implies the existence of an extra force to balance that of gravity, thus preventing the inward collapse of the Universe.

But if, like me, you get the impression that this is all a bit hard to accept, you'll appreciate an editorial in the same edition of *Nature*. It observes that "if cosmologists are forced to start throwing around several kinds of dark matter along with a cosmological constant, scepticism is bound to arise". Really?

Improved electrodes will mean better image for CCDs

Solid state image sensors such as the well-established CCDs have ousted thermionic and vacuum devices in a wide variety of applications. But just as vidicons and the lead oxide camera tubes underwent continuous development and improvement, the same is now proving true of solid state image sensors, particularly in the search for new electrode materials.

CCDs can be found everywhere; from the home camcorder to the biggest astronomical telescopes in the world. In principle, the chips all consist of a series of narrow light-transmitting electrodes applied to oxidised wafers of silicon.

If light falls on the electrodes, electrons are released into the underlying silicon. By applying appropriate voltage pulses the packages of electrons are sampled and converted into an output, and the amount of charge under each electrode is a measure of the light absorbed.

ITO replaces polysilicon

The present generation of image sensors uses polycrystalline silicon as the electrode material because it is easy to control and process. Only disadvantage is that it absorbs light which in turn reduces the sensitivity of the sensor. But that may soon become a thing of the past, thanks to research by Christ Weijtens at the Philips Research Laboratories in Eindhoven.

Weijtens' study, part of a project in the Esprit programme, has shown that indium tin oxide (ITO) can be used successfully as an electrode material to replace polysilicon.

ITO, one of the few available alternatives, is both conductive and transparent, its only problem being that it tends to cause troublesome crystal defects in the SiOx oxide layer of the sensor. Defects result not only in a loss of sensitivity but also in visible faults.

Weijtens found that one of the causes of the damage to the crystal lattice is the charging of the non-conducting SiOx layer by the very process used to deposit the ITO.

Production

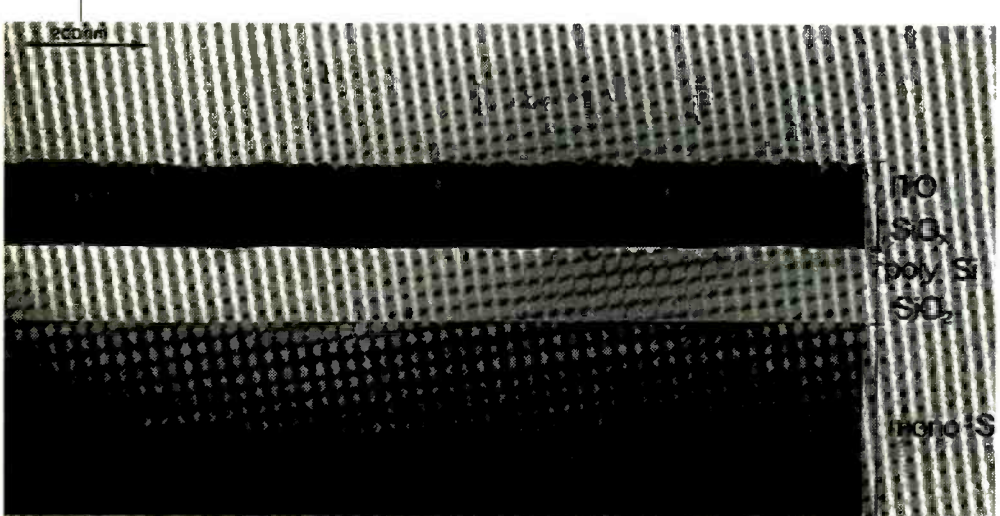
First step in producing ITO electrodes consists of a magnetron sputter arrangement in which indium and tin atoms are forced out of a cathode by ion bombardment at low pressure in an atmosphere of argon and oxygen.

The indium and tin atoms combine with the oxygen to form ITO, deposited on an oxidised silicon wafer, and thereafter the electrode structure is etched using a photoresist. By applying a very thin, almost transparent, conductive layer of polycrystalline silicon prior to the ITO, Weijtens found that the charging of the SiOx layer is prevented.

Another advantage of this extra layer is that the SiOx layer is clean and well defined.

Using a final brief heat treatment at 950°C with subsequent heat treatment at a lower temperature, any remaining crystal defects are reduced considerably.This improves the light absorption and also the electrical properties of the chip.

Although development is still at the laboratory stage, it promises the possibility of a new generation of cheaper and considerably better image sensors.



sIndium and tin atoms, forced out of a cathode by ion bombardment, combine with oxygen to form ITO, deposited on an oxidised silicon wafer. Electrode structure is etched using a photoresist. A thin conductive layer of polycrystalline silicon prevents charging of the SiOx layer.

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Atomic power drives megamega memories

Last year IBM scientists Don Eigler and Erhard Schweizer achieved something of a publicity scoop by printing the company logo with individual xenon atoms on a nickel substrate. Now Hitachi scientists have now taken the technology another stage forward by detaching individual atoms from what was previously a uniform flat surface. For the electronics industry the eventual result could be memories a million times denser than current devices.

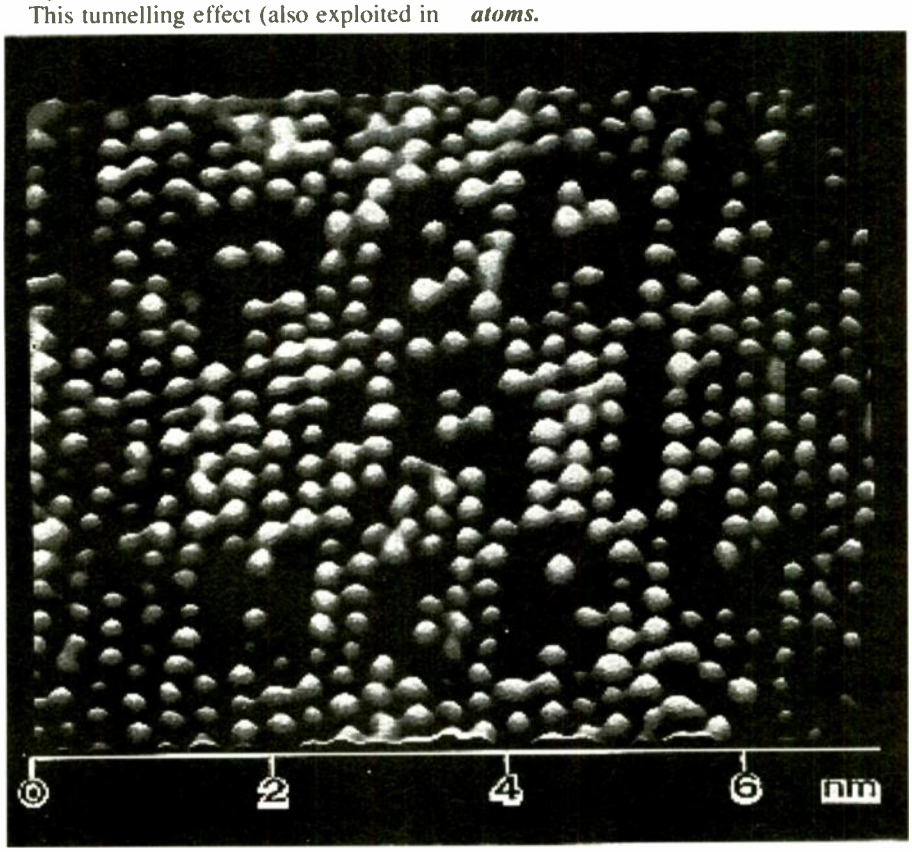
It was perhaps appropriate for IBM to be making the running in the original work, since its scientists had previously won a Nobel prize for inventing the enabling technology. Moving individual atoms around and, even more surprisingly, being able to produce an image of the result is an incredible feat considering that the smallest speck of visible dust may contain around 10^{18} atoms.

The secret lies in a device called the scanning tunnelling microscope (STM) which has revolutionised our ability to study matter down to atomic dimensions.

This tunnelling effect (also exploited in the tunnel diode) is critically dependent on the gap between a pair of charged conductors: increase the gap and fewer electrons can traverse it. If one of the conductors is placed in a feedback loop so that the electron flow remains constant, then it will hover at a specified distance from the other conductor.

Microscopic tracking

In the case of a practical STM the movable conductor is made in the form of a very fine needle that floats over the fixed specimen. And because it is forced to maintain a precise spacing, the needle, when moved sideways, will track the microscopic hills and valleys of the specimen in a manner analogous to the stylus of a record player. The only difference is that the STM needle can track hills and valleys on the atomic scale without ever touching them.



"Peace '91 HCRL" written in molybdenum disulphide by removing sulphur atoms.

Last year's spectacular result came about when Eigler and Erhard developed the STM beyond that of a mere passive, diagnostic tool. Using higher voltages on the probe and cooling their samples to near absolute zero they managed to nudge 35 xenon atoms into specified locations in the nickel lattice.

Hitachi scientists have now taken STM technology another stage forward by doing almost the reverse, detaching individual atoms from the uniform flat surface.

What's more, they've proved they can do it at room temperature, a significant achievement.

As with the IBM work the method involved scanning the surface of the substrate using a voltage and spacing to give a clear picture of that surface, but without changing it. The STM needle was then moved even closer — a mere 3 Angstroms — and given a pulse of a higher voltage. A tungsten probe floating over a surface of molybdenum disulphide was used in the experiment and when the surface was subsequently checked using the STM in its diagnostic, or picture-taking mode, it was found that each pulse had removed a single sulphur atom from the molybdenum disulphide.

Although further studies will be necessary to understand the atom detachment mechanism, Hitachi researchers believe that the atoms are removed by field evaporation, a phenomenon in which atoms fly into the surrounding space when the interatomic binding energy is overcome by a strong electric field.

Excising individual atoms with high precision has the same practical goal as all research on atomic manipulation: higher density memories and atom-scale active devices. In memory terms alone a Hitachi spokesman suggests that STM technology might improve storage capacity by a factor of 10^6 compared to today's 4Mbit drams.

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

Editorial survey: use the infomation card to evaluate this article. Item A.

1993 aim for Europe Tflops supercomputer

A group of European academics and computer engineers is close to completing a design for a supercomputer which can process 1Teraflop/s (1×10^{12} floating point operations/s).

European Teraflop Initiative, which includes academics from Cern and the University of Edinburgh as well as companies like Parsytec and Meiko, believes it can build a working machine by 1993. This is despite a recent EC report which found that Europe would have to invest about £750million each year to catch up with the supercomputer technology lead built by the US and Japan.

The working group has welcomed the report's call for funding, especially for developing a market for European-built supercomputers. But members feel that the expertise needed to make the machine and write software already exists.

ETI's machine will use about 50 000 microprocessors all running in parallel.

One of the engineers working on the design said that the biggest problem would be finding a suitable micro. "To build a computer with 10 000 processors you need to have very small nodes, with less than 10 glue logic chips per node. This would be very hard with the [Intel] i860." he said.

But he expected it to be more workable with the H1 version of the transputer.

$6.5m chance to soak up the sun

A three-year programme has been drawn up by the Solar Energy Research Institute (Seri) to develop large area, high efficiency, multi-junction thin film solar electric generating modules that convert sunlight directly into energy.

Under the programme Solarex and Seri will share the $6.5million cost of developing advanced modules demonstrating a stable conversion efficiency of 12%. The contract also targets development of a small area (1cm^2) device with a 14% conversion efficiency.

Unlike typical single-junction solar cells, multi-junction solar electric devices are constructed of several solar cells placed on top of one another, each being designed to capture a different portion of the solar spectrum.

Multi-junction structures have already demonstrated impressive gains in stability over earlier single-junction devices.

Risc strategy

Mips Computer Systems has unveiled its plans for the R4000 risc microprocessors. The 64-bit devices, when they eventually appear as silicon, will use an eight-stage pipeline to execute two code instructions every clock cycle.

The company has plenty to say about the technical points of its device; its cache page lock mode, addressable memory range and pipeline stage bypass circuitry among others. But the most interesting features are very much more basic.

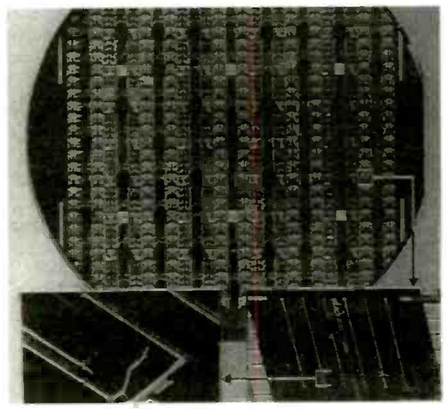
There will be two versions of the chip. One is housed in a 450 pin grid array and the other in a 180 lead package.

Something which will certainly be left off the smaller size is the dynamic real world delay compensation circuitry. The 450 pin device will have two connections shorted together on the circuit board, allowing the chip to measure and accommodate variations in the signal delay between the chip die and the board. If a chip maker produces a "faster" package than another, the user won't have to worry about the difference.

20 000 lasers on an IC

Scientists at IBM's Zurich Research Laboratory have developed a technique to build 20 000 lasers on a round semiconductor 2-in across. It is claimed to be the first time anyone has been able to mass-produce and mass-test semi-conductor lasers on a complete wafer.

In the new process narrow trenches 0.005-in deep are etched into the AlGaAs



semiconductor wafers to form laser mirrors. Previously mirrors were formed individually for each laser by cleaving the semiconductor crystal, and the lasers had to be individually tested. Now IBM can fabricate and test thousands of lasers at once on an uncut wafer.

Shown above is a wafer with 5000 lasers. Enlarged pictures show an array of six individual lasers and accompanying photo diodes, and a single laser and photo diode

Chip ship: The space Industries sheet float zone furnace is used for high-temperature superconductor materials processing research in microgravity environment aboard the Nasa KC-135 parabolic aircraft. The industrialised Macintosh-based system is controlled by National Instruments' LabView2.

IT'S GOING TO BE A WIRELESS WORLD

The ISSCC, held every year in February in San Francisco, is the premier world forum for announcing advances in microelectronics. 1991 conference papers described new integrated circuits and gave a good indication of where electronics leaders are directing their R&D. David Manners reports on progress to a portable and wireless world.

Portable products and wireless communications are now the two big areas of electronics activity for leading technologists, judging by the International Solid State Circuits Conference (ISSCC) held earlier this year.

As a result, flat-panel displays, ultra-low power memory and technological options for personal wireless communication are all hot issues for current R&D.

Looking first at displays, no less an authority than IBM's TJ Watson Research Centre is saying that full-colour, flat-panel, thin-film transistor (TFT) liquid-crystal displays are the future for computer and television viewers, replacing the bulky and power-hungry cathode ray tube. IBM believes that 1991 will be the year in which these panels will be manufactured in quantities of more than a million.

A keynote speaker from Toshiba supported that view. Perhaps it is no coincidence that IBM and Toshiba have a joint venture to manufacture large, colour active-matrix LCDs. First factory comes on-stream this Spring.

Amorphous or polysilicon

According to an ISSCC panel, there are two main technology options for building large flat panels. One is to use amorphous silicon TFTs and the other is to use polysilicon TFTs.

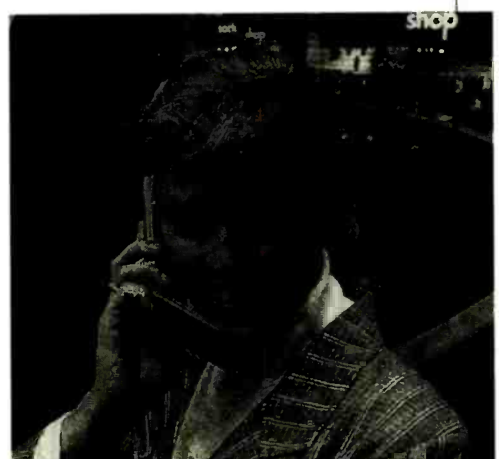
Disadvantage of amorphous silicon is that drive currents are typically 1000 times smaller than with the n-channel single-crystal mosfet driver chips needed to operate the display. For a mega-pixel display, several thousand connections need to be made to the active matrix, increasing costs and presenting reliability problems.

On the other hand, polysilicon TFTs offer drive currents about one tenth those of single-crystal devices and both n-channel and p-channel devices are available. This makes it possible to integrate cmos driver and interface circuitry directly on the glass with the display, greatly reducing the number of external chips and connections.

But Nippon Telephone and Telegraph (NTT) believe that the amorphous silicon approach could come up against a technical barrier at 1M pixels per panel. NTT's view is that for larger, denser, panels the move must be made from amorphous silicon to polysilicon, integrating the active matrix, driver, interface and defect-tolerant circuits on the same glass substrate. Low temperature polysilicon processing would have to be mastered.

Sharp's assessment is that whereas both approaches are feasible, polysilicon seems the best solution for high resolution displays, though Hitachi think that integrating driver and interface circuitry onto the glass will be more effective in reducing the number of chips and connections than the overall replacement of peripheral circuits by polysilicon TFTs.

Whether amoprphous silicon or polysilicon becomes the dominant technology, drive requirements will differ from CRTs. CRTs are scanned and require a serial analogue input; active matrix displays write a line at a time and require parallel inputs. If polysilicon drivers are to be integrated with the displays then new circuit design techniques may be required.



Better memory

Much consideration was given at the ISSCC to the conflicting pressures on selecting different types of memory store, principally in relation to the new generations of portable computer.

The problem is essentially that if you use disks, you need bulky revolving mechanisms requiring hefty batteries. It follows that the resulting machine is heavy, large and has just a two or three hour battery life.

Memory chips give the advantages of lightness, cheapness and 40 to 60 hours of battery life; but your removable storage medium — a card rather than a floppy — is compatible with precious little.

No one seems to have resolved this dilemma yet, although it was pointed out by speakers from Intel that it is possible to produce a chip which is non-volatile, can be erased electrically rather than by UV, and because like dram it needs only one transistor to make a memory cell capable of storing a binary digit, has the potential to be both dense and cheap.

The chip is called a flash eeprom (electrically erasable programmable read only memory) and it currently costs about £7-10 for a 1Mbit device, allowing a credit-

card-sized 1Mbyte memory card to be made for £56-80.

Cheaper flash memory

£80 is a heavy price for a removable storage medium, but to bring down future costs Intel is projecting a very quick climb up the density scale for flash chips to 4Mbit in 1992 and to 16Mbit in 1994.

As if to demonstrate that such a timescale is possible, Mitsubishi gave a paper at the conference describing a 16Mbit flash eeprom which could be made in a similar manner, and so for much the same cost, as a conventional eprom (erasable programmable read only memory — erased by exposure to ultra violet).

Credit-card-sized memory cards (sometimes called solid-state discs) with up to 24 eeprom chips, suggest the possibility of a removable storage medium providing 48Mbyte of non-volatile but electrically erasable and alterable memory.

As well as being useful for removable memory storage, it was argued at an ISSCC evening session that flash chips could become suitable for fixed, internal storage in computers. The justification was that cost-per-byte of flash chip storage was on a steeper learning curve than the cost-per-byte of hard-disk storage. An Intel panellist projected that by 1996, with the 64Mbit chip generation, the cost of flash would be less, byte-for-byte, than the cost of hard disk.

Communications

The ideal for personal communications, summarised at ISSCC by NTT, will be when: "Anyone can communicate instantly with anyone else anywhere else". The medium for achieving this ideal is advanced cordless telephony using radio waves.

Combining analogue and digital

One of the chip technologies needed to achieve low-cost, lightweight portable telephone equipment is the amalgamation of analogue circuitry and digital circuitry on one chip.

At the ISSCC, a panel session devoted to mixed-signal technology addressed the question: "Can simulation ensure first-pass silicon success?". Its conclusion was "so far, no".

Storing analogue wavefo-ms directly

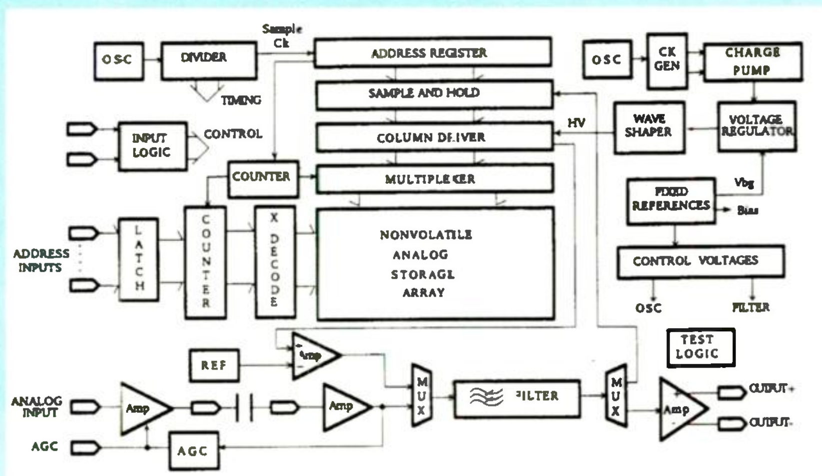
Chips for computer memory storage are not the only new kinds of storage chips under current examination.

For the first time, a chip has been presented which stores analogue waveforms without any need for conversion into digital form. Silicon Valley start-up company Information Storage Devices described a technique to store 16s of analogue waveforms at 8MHz using 128K eeprom cells.

The technique eliminates A-to-D and D-to-A converters in storing analogue signals and is said to allow storage of eight times more information than can be achieved by digital techniques. In other words, using digital technology, a 1Mbit chip would be needed to offer equivalent storage to ISD's 128K device.

The chip can interface directly to a microphone or loudspeaker without the need for other active components and reproduction is claimed to be better than telephone quality.

Short cut: direct storage of analogue waveforms without need for A-to-Ds.



Advent of chips to accomplish this aim has seen prices of equipment drop dramatically — a process which will continue.

According to UK's Shaye Communications, at an ISSCC evening discussion session, 1991 will see an explosion in the market as manufacturers produce standardised products based on the cordless telephone 2 (CT2) system. Overcrowding of the frequency spectrum has meant these 'phones are moving from the 45MHz band to 902-928MHz.

At the moment the US cordless telephone system uses analogue techniques, but digital systems are needed to cope with the demands on available channels.

Two systems are proposed for a digital system in the USA: time-division multiple access (TDMA) amd code-division multiple access (CDMA).

TDMA uses quadrature phase shift keying (QPSK) and CDMA uses frequency-hopping spread-spectrum techniques, which are also used for Europe's proposed group special mobile (GSM).

By using microcells, according to the panel, wireless private branch exchanges (PBXs) could become a reality during the 1990s. Such PBXs would need to operate in the GHz range and would allow communication from anywhere in a building to anywhere in the outside world.

All in all, the message from 1991 ISSCC was a little different from the traditional ISSCC message of "Look what we can do". This year it seemed to be saying "Look what we can do *for you*". Instead of technology for its own sake, the world's electronics leaders are at last focusing their thinking on serving the shape of a future world, where electronic products are pocketable and wireless.

Editorial survey: use the information card to evaluate this article. Item B.

INSIDE MIXERS

A top-end mixing console should represents the highest form of audio design. Soundcraft's chief designer Doug Self describes the technology of acoustic excellence.

A large mixing console arguably represents the most demanding area of audio design. The steady advance of digital media demands that every part of the chain that takes music from performer to consumer must be near-perfect, as the comfortable certainty that everything will be squeezed through the quality bottleneck of either analogue tape or vinyl disc now looks very old-fashioned.

Competition to sell studio time becomes more cut-throat with every passing week, and it is clear that advances in console quality must not harm cost-effectiveness. The only way to reconcile these demands is to innovate and to keep a very clear view as to what is really necessary to meet a demanding specification: in other words the way forward is to use conventional parts in an unconventional way, rather than simply reaching for the most expensive op-amp in the catalogue.

Technical problems that must be overcome in a professional mixing console are many. A large number of signals flow in a small space and they must be kept strictly apart until the operator chooses to mix them; crosstalk must be exceedingly low.

Soundcraft's Series 3200 mixing console, which the company claims to be possibly the best-performing instrument ever built.

Up to 64 input channels, each with many stages, all have the potential to add distortion and noise to the precious signal. Even summing these signals together, while sounding trivially easy, is in practice a major challenge. In short, requirements are much more demanding than those for the most expensive hi-fi equipment, because degradation introduced at this stage can never be retrieved.

Major functions of consoles are largely standardised, although there is much scope for detailed variation. **Figure 1** shows the system diagram, and the technique of multi-track recording is explained in the panel.

Figure 2 shows a typical input channel for a mixing console. The input stage provides switchable balanced mic and line inputs; the mic input has an impedance of 1-2kΩ, which provides appropriate loading for a 200Ω mic capsule, while the line input has a bridging impedance of not less than 10kΩ. This stage gives a wide range of gain control and is followed immediately by a high-pass filter (usually -3dB at 100Hz) to remove low-frequency disturbances.

The tone-control section (universally known in the audio business as "EQ" or equalisation) typically includes one or more mid-band resonance controls as well as the usual shelving Baxandall-type high and low controls. Channel level is controlled by a linear fader and the panpot sets the stereo positioning, odd group numbers being treated as left, and even as right. The PFL (prefade-listen) switch routes the signal to the master module independently of all other controls; a logic bus signals the master module to switch the studio monitoring speakers from the normal stereo mix bus to the PFL bus, allowing any specific channel to be examined in isolation.

Figure 3 shows a typical group module and **Fig. 4** the basics of a master section; a manual source-select switch allows quality checking of the final stereo recording and two solid-state switches replace the stereo monitor signal with the PFL signal whenever a PFL switch anywhere on the console is pressed.

AUXILIARY SENDS; FOLDBACK AND EFFECTS.

The auxiliary sends of a console represent an extra mixing system that works independently of the main groups; the number and configuration of these sends have a large effect in determining the overall versatility of the console. Each send control provides a feed to a console-wide bus; this is centrally summed and then sent out of the console.

Sends come essentially in two kinds: prefade sends, which are taken from before the main channel fader, and postfade sends, which take their feed from after the fader, so that the final level depends on the settings of both. There may be anything from one to twelve sends available, often switchable between pre and post. Traditionally, this means laboriously pressing a switch on every input module, since it is most unlikely that a mixture of pre and post sends on the same bus would be useful; the 3200 minimises the effort by setting pre/post selection for each bus from a master switch that controls solid-state pre/post switching in each module.

Prefade sends are normally used for "foldback"; i.e. sending the artist a headphone feed of what he/she is perpetrating, which is important if electronic manipulation is part of the creative process, and essential if the artist is adding extra material that must be in time with that already recorded. In the latter case, the existing tracks are played back to the artist via the prefade sends on the monitor sections.

Postfade sends are used as effects sends; their source is after the fader, so that the effect will be faded down at the same rate as the untreated signal, maintaining the same ratio. The sum of all feeds to a given bus is sent to an external effects unit and the output of this returned to the console. This allows many channels to share one expensive device (this is particularly applicable to digital reverb.) and is often more appropriate than the alternative of patching a processor into the channel insert point.

"Effect returns" may be either modules in their own right or a small subdivision of the master section. The returned effect, which may well now be in stereo, the output of a digital reverb., for example, is usually added to the stereo mix bus via level and pan controls. EQ is also sometimes provided.

Microphone inputs

The microphone preamplifier is a serious design challenge. It must provide from 0 to 70dB of gain to amplify deafening drum-kits or discreet dulcimers, present an accurately balanced input to cancel noise pickup in long cables and generate minimal internal noise. It must also be able to withstand +48V DC suddenly applied to the inputs (for phantom-powering internal preamps in capacitor mics) while handling microvolt signals. The Soundcraft approach is to use standard

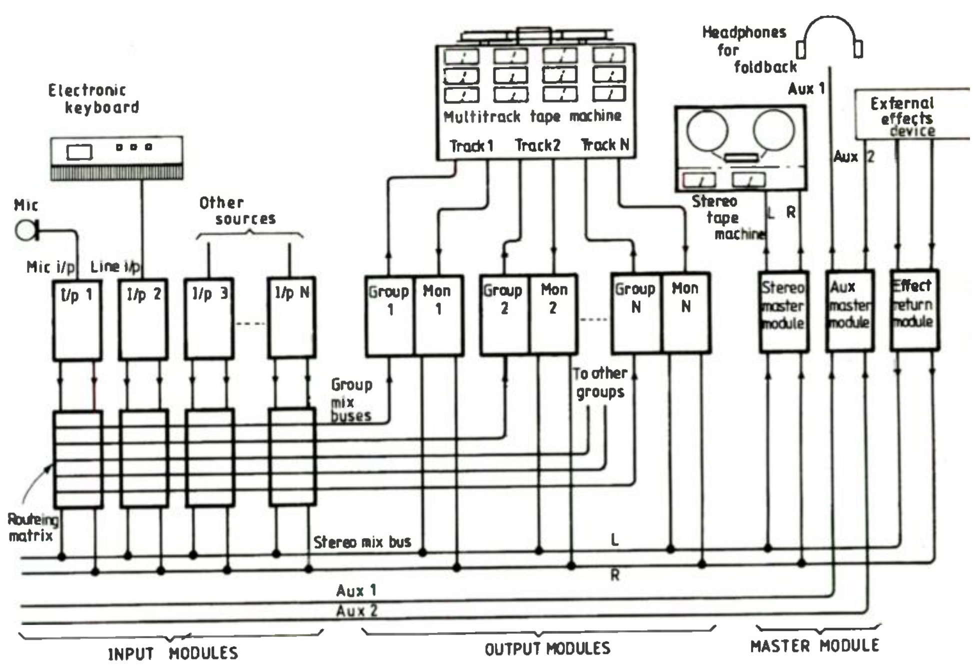


Fig.1. System diagram of complete mixing console, showing division into inputs, group monitor contributions and master modules. Routeing matrix determines which group of inputs shall be fed to a given track on the multi-track tape machine. Several channels share one effects device.

parts, which are proven and cost-effective through quantity production, in new configurations. The latest mic preamplifier design, as used on the 3200, is new enough to be covered by patent protection.

It is now rare to use input transformers to match the low-impedance (150-200Ω) microphone to the preamplifier, since the cost and weight penalty is serious, especially when linearity at low frequencies and high levels is important. The low-noise requirement rules out the direct use of op-amps, since their design involves compromises that make them at least 10dB noisier than discrete transistors at low impedance.

This circuit, shown in **Fig.5**, therefore uses a balanced pair of low-noise, low-R_b p-n-p transistors as an input stage, working with two op-amps to provide load-driving capability and raw open-loop gain to linearise signal handling. Preamplifier gain is spread over two stages to give a smooth 0-70dB gain range with the rotation of a single knob. This eliminates the switched 20dB attenuator that is normally required to give the lower gain values, not only saving cost and complication, but also avoiding the noise deterioration and CMRR degradation that switched attenuators impose. The result is an effective input stage that is not only quieter, but also more economical than one using specialised low-noise op-amps.

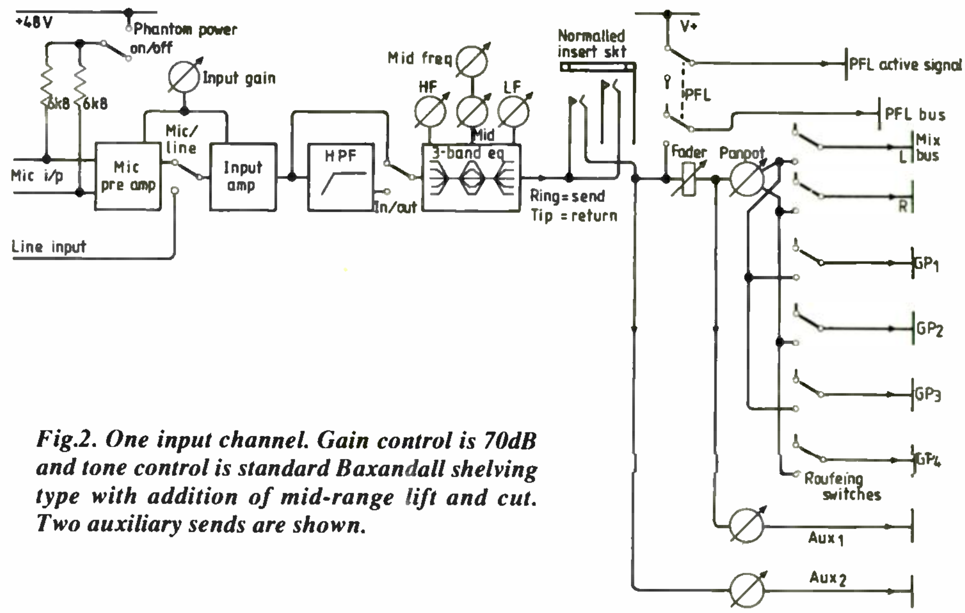


Fig.2. One input channel. Gain control is 70dB and tone control is standard Baxandall shelving type with addition of mid-range lift and cut. Two auxiliary sends are shown.

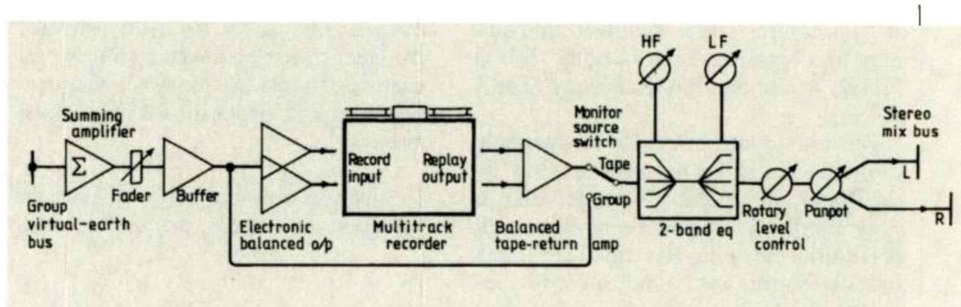
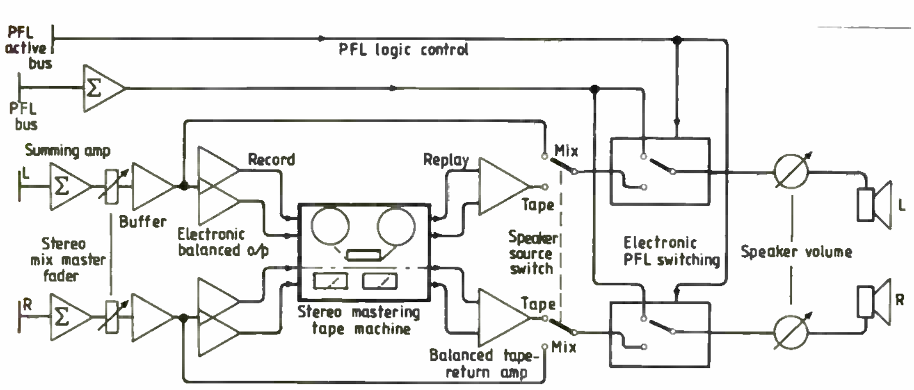


Fig.3. Block diagram of typical group module, showing switching between direct output and tape replay for monitoring purposes.

EQ

Since large recording consoles need sophisticated and complex tone-control systems, unavoidably using large numbers of op-amps, there is a danger that the number of active elements required may degrade the noise performance. A typical mid-band EQ that superimposes a ±15dB resonance on the flat unity-gain characteristic is shown in **Fig. 6**. A signal is tapped from the forward path, put through a state-variable band-pass filter which allows control of centre-frequency and Q, and then added back. To improve noise performance, the signal level at all locations (in all conditions of frequency, Q, and boost/cut) was assessed, and it proved possible to double the signal level in the filter over the usual arrangement, while maintaining full headroom. The noise generated is thus reduced about 6dB.

Fig.4. Block diagram of master module, with tape send/replay switching and automatic PFL switching.



Panpot

To give smooth stereo panning without unwanted level changes, the panpot should theoretically have a sine/cosine characteristic; such components exist, but they are prohibitively expensive and so most mixing consoles use a dual linear pot. with its law bent by a pull-up resistor, as shown in **Fig.7a**. This not only gives a mediocre approximation of the required law, but also limits the panning range, since the pull-up signal passes through the wiper contact resistance (usually greater than the end-of-track resistance) and limits the attenuation the panpot can provide when set hard left or right. This limitation is removed in the Soundcraft active panpot shown in **Fig.7b** by replacing the pull-up with a negative-impedance-converter that modulates the law-bending effect in accordance with the panpot setting, making a close approach to the sine law possible. There is no pull-up at the lower end of the wiper travel, when it is not required, so the left-right isolation using a good-quality pot. is improved from approx -65dB to -90dB. This has also been made the subject of patent protection.

Summing

One of the main technical challenges in console design is the actual mixing of signals. This is done almost (but not quite) universally by virtual-earth techniques, as in **Fig.8a**. A summing amplifier with shunt feedback is used to hold a long mixing bus at apparent ground, generating a sort of audio black hole; signals fed into this via mixing resistors apparently vanish, only to reappear at the output of the summing amplifier, as they have been summed in the form of current. The elegance of virtual-earth mixing, as opposed to the voltage-mode summing technique in **Fig.8b**, is that signals cannot be fed back out of the bus to unwanted places, as it is effectively grounded, and this can save massive numbers of buffer amplifiers in the inputs.

There is, however, danger in assuming that a virtual earth is perfect; a typical op-amp summer loses open-loop gain as frequency increases, making the inverting input null less effective. The 'bus residual' (i.e. the voltage measurable on the summing bus) therefore increases with frequency and can cause inter-bus crosstalk in the classic situation with adjacent buses running down an IDC cable.

Increasing the number of modules feeding the mix bus increases the noise gain; in other words the factor by which the noise of the summing amplifier is multiplied. In a large console, which might have 64 inputs, this can become distinctly problematic. The Soundcraft solution is to again exploit the low noise of discrete transistors coupled to fast op-amps, in configurations similar to the mic preamps. These sum amplifiers have a balanced architecture that inherently rejects supply-rail disturbances, which can otherwise affect LF crosstalk performance.

As a console grows larger, the mix bus system becomes more extensive, and therefore more liable to pick up internal capacitive crosstalk or external AC fields. The 3200 avoids internal crosstalk by the use of a proprietary routeing matrix construction which keeps the unwanted signal on a bus down to a barely measurable -120dB. This is largely a matter of keeping signal voltages away from the sensitive virtual-earth buses. Further improvement is provided by the use of a relatively low value of summing resistor; this also keeps

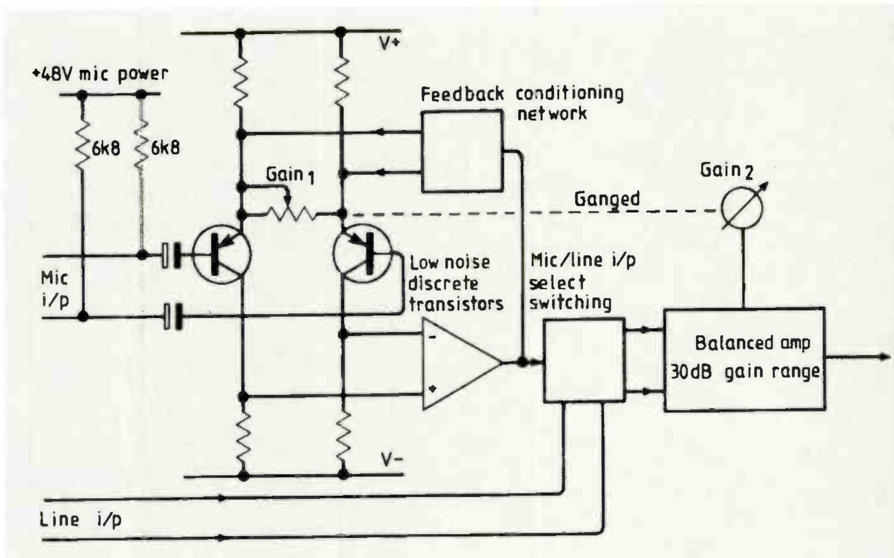


Fig.5. Low-noise microphone amplifier with wide gain range and balanced line output. Transistors in first stage avoid noise problem of op-amps.

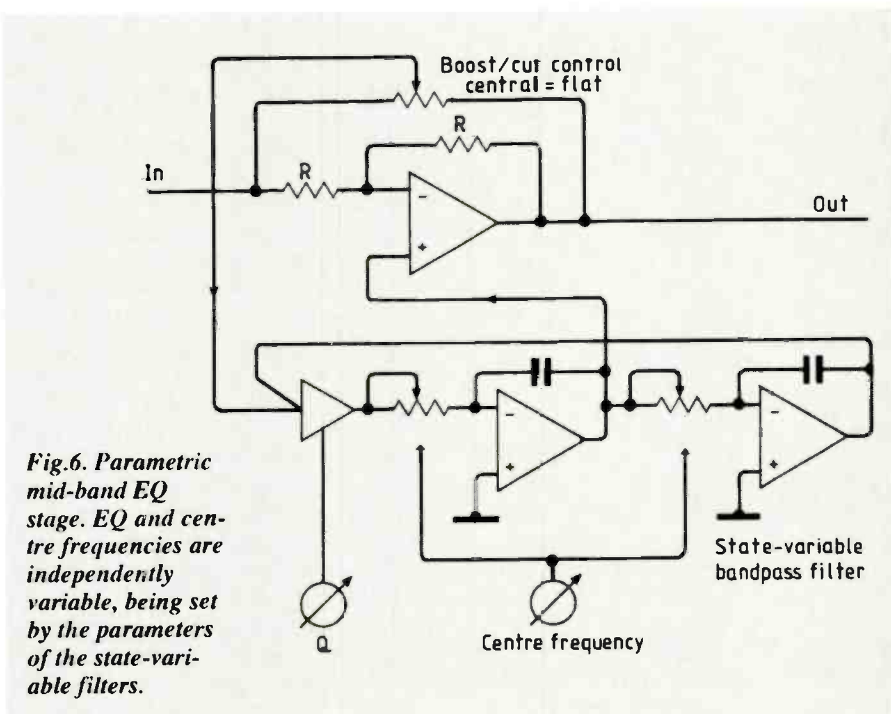


Fig.6. Parametric mid-band EQ stage. EQ and centre frequencies are independently variable, being set by the parameters of the state-variable filters.

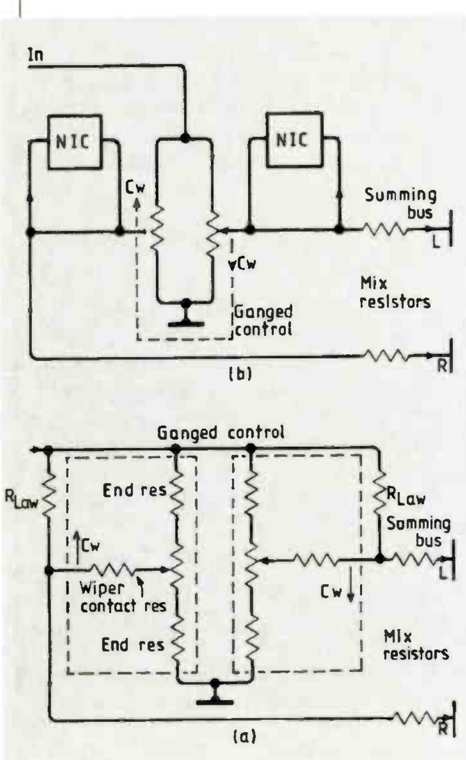


Fig.7. Standard panpot circuit at (a) showing how pull-up resistor draws current through wiper contact resistance, which is usually greater than the end resistance of the pot., limiting maximum attenuation. Arrangement at (b) uses NICs to replace pull-up to modulate law with panpot setting. Left/right isolation increased from -65dB to -90dB.

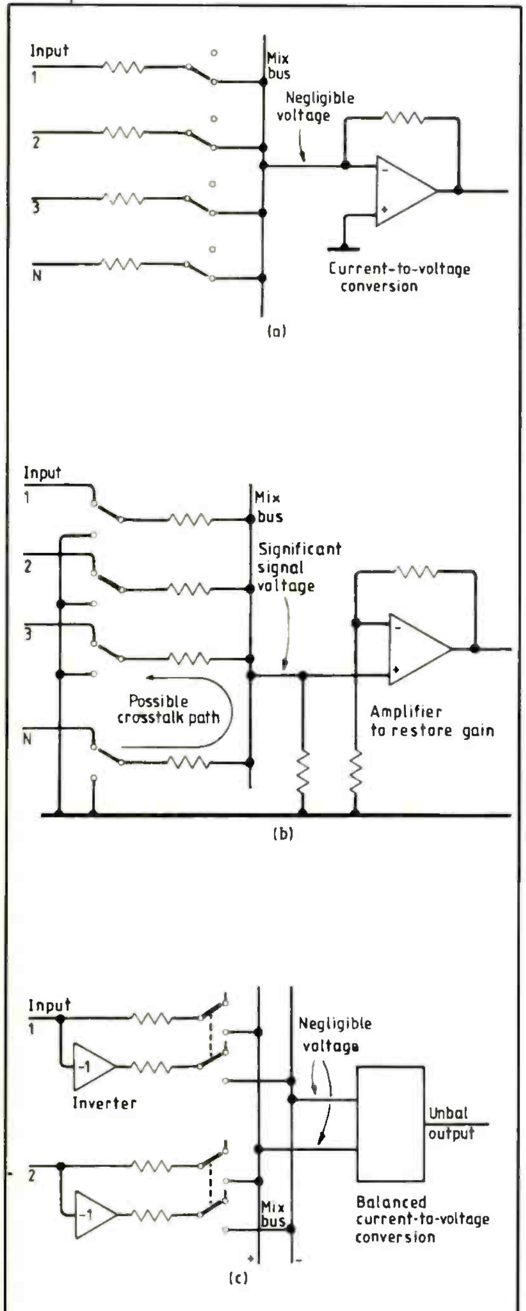


Fig.8. Virtual-earth summer at (a) effectively eliminates cross-talk, since there is almost no signal at the summing point. Voltage-mode circuit at (b) allows cross-talk. Balanced virtual-earth summing circuit at (c) requires a separate inverter for each channel to provide the anti-phase signal.

THE TECHNIQUE OF MULTITRACK RECORDING.

Multitrack recording greatly enhances the flexibility of recording music. The availability of a number of tape tracks (anywhere between 4 and 32 on one reel of tape) that can be recorded and played back separately allows each instrument a dedicated track, the beauty of this being that one mistake does not ruin the whole recording; only a single part need be done again. The multitrack process is in two basic halves; recording individual tracks (or "tracklaying") and mixdown to stereo.

Recording. Normally only one or two parts are recorded at once, though it quite possible to dedicate five or six tracks to a drum kit. The initial sound, whether captured by a microphone or fed in directly from a synthesiser line output, is usually processed as little as possible before committing it to tape; subsonic filtering and perhaps compression or limiting are used, but most effects are carefully avoided because they are usually impossible to undo later. You can easily add reverberation, for example, but just try removing it.

Recording is performed via the input modules, this being the only place where microphone preamps are fitted. The inputs are mixed together into groups if required; performers doing backing vocals might use four or five microphones, but these would almost certainly be mixed down to a stereo pair of groups at the recording stage, so that only two tape tracks are taken up. A bank of switches on each input module determines which group shall be fed; this is known as the routeing matrix. Combined group outputs are then sent to tape; however a "group" is usually used even if only one signal is being recorded, as this is the part of the console permanently connected to the multi-track.

It is clearly essential that new parts are performed in time with the material already on tape and also that the recording engineer can make up a rough impression of the final mix as recording proceeds. Thus continually replaying already-recorded material is almost as important as recording it in the first place. During recording, the tape tracks already laid down are replayed through "monitor sections" which are usually much-simplified inputs giving limited control; this keeps the more flexible inputs free for material that is actually being recorded. One of the major features of the 3200 is that the monitor sections are unusually capable, having facilities almost identical to the inputs and allowing much more accurate assessment of how the mix is progressing, reducing learning time for operators.

Mixdown.When the tracklaying process is complete, there are 16 or more separate tape tracks that must be mixed down to stereo. Major manipulations of sound are done at this mixdown stage; since the multitrack tape remains unaltered, the resulting stereo being recorded on a separate two-track machine, any number of experiments can be performed without doing anything irrevocable.

Multitrack replay signals now enter the console through the input channels, so that the maximum number of facilities are available. Linear channel faders set the relative levels of the musical parts, while the rotary panpots (panoramic potentiometers) define the placement of instruments in the stereo sound field by setting the proportion of signal going to left and right mix buses. The monitor sections are now redundant, and can therefore be used either as extra inputs to the stereo mix, perhaps for keyboards, or to return effects.

Virtual mixing. The advent of computer-based sequencers has given rise to the term "virtual mixing". Keyboard/synthesiser parts of the musical masterwork are not committed to multitrack, but instead stored in the form of MIDI sequencer data. This can be replayed at any time, providing means of synchronising it to the acoustic parts on the multitrack exist; this requires one tape track to be dedicated to some form of timecode.

Advantages are, firstly, that this gives almost any number of extra "virtual tracks", and secondly that the synthesiser parts suffer minimal degradation as they avoid one generation of tape storage.

the noise down, although since it drops as the square-root of the resistor value, at best, there is a clear limit to how far this approach will work before drive power becomes excessive; 4.7kΩ is a reasonable minimum value.

External magnetic fields, which are poorly screened by the average piece of sheet steel, are rejected by the balanced nature of the 3200 mix buses, shown in **Fig.8c**. The operation is much the same as a balanced input; each group has two buses, which run physically as close together as possible and the group reads the difference between the two, effectively rejecting unwanted pickup. The two buses are fed in antiphase from each input, effectively doubling the signal level possible for a given supply voltage. Overall mixing noise is reduced by 3dB, the signal level is 6dB up and the noise, being uncorrelated for each bus, only increases by 3dB.

The obvious method of implementing this is to use two summing amplifiers and then subtract the result. In the 3200, this approach is simplified by using one symmetrical summing amplifier to accept the two antiphase mix buses simultaneously; this reduces the noise level as well as minimising parts cost and power consumption. Theconfiguration is very similar to that of the balanced mic amp., and there-

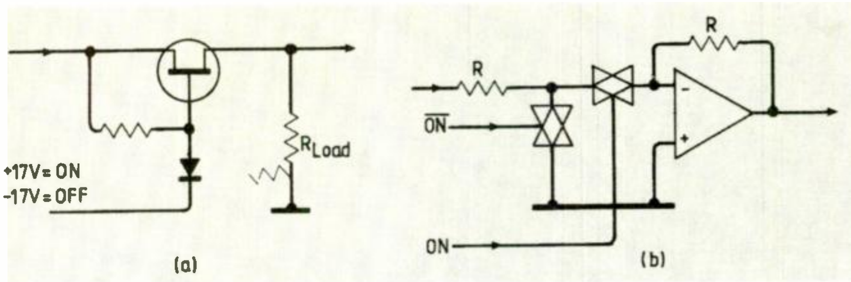


Fig.9. Hard switching with jfets in voltage mode (a) and with analogue gates in the current mode (b), which prevents gate elements from being driven outside their voltage capabilities.

fore gives low noise as well as excellent symmetry.

Solid-state switching.

There are two main applications for electronic switching in console design. The first is "hard" switching to reconfigure signal paths, essentially replacing relays with either jfets (**Fig. 9a**) or 4016-type analogue gates which, since they are limited to 18V rails and cannot handle the full voltage swing of an op-amp audio path, must be used in current-mode, as shown in **Fig.9b**. Note that when gate 1 is off, gate 2 must be on to ensure that a large voltage does not appear on gate 1 input. Full-voltage range gates do exist but are very expensive.

Secondly, there is channel muting; this not a hard switch, since an unacceptable click would be generated unless the signal happened to be at a zero-crossing at the instant of switching; the odds are against you. The 3200 therefore implements muting as a fast-fade that takes about 10ms; this softens transients into silence while preserving time-precision. It is implemented by a series-shunt jfet circuit, with carefully synchronised ramp voltages applied to the fet gates.

Performance factors

Primary requirements of modern consoles are very low noise and minimal distortion. Since a comprehensive console must pass the audio through a large number of circuit stages (perhaps over 100 from microphone to final mixdown) great attention to detail is essential at each stage to prevent a build-up of noise and distortion; the most important trade-off is the impedance of the circuitry surrounding the op-amp, for if this too high Johnson noise will be increased, while if it is too low an op-amp will exhibit non-linearity in struggling to drive it.

The choice of device is also critical, for cost considerations discourage the global use of expensive chips. In a comprehensive console like the 3200 with many stages of signal processing, this becomes a major concern; nonetheless, after suitable optimisation, the right-through THD remains below 0.004% at 20dB above the normal operating level. At normal level it is unmeasurable

Editorial survey: use the information card to evaluate this article. Item C.

CHIPPING AT THE PAST

Archaeology is ripe for automation. A typical dig involves thousands of positional measurements required to produce a 3-D image of the site. Archaeologist Helen Geake and technology writer Elisabeth Geake bring past and present together.

If you saw any of the *Down to Earth* archaeology programmes on Channel 4 before Christmas, you will be aware that archaeology these days is pretty high-tech. Electronics and computers are a routine part of all but the smallest excavations.

They are used throughout a project, from electronic surveying and metal detecting before digging begins to reconstruction with computer-aided design and 3D animation programs when the dig is finished.

Now archaeology has beaten electronics and engineering, and become the first discipline to use the Gridpad computer in anger. The Gridpad, described in the panel, is a hand-held computer without a keyoard; instead, it has a brass stylus for writing on its A5-sized screen. It recognises handwriting and can store drawings and signatures as bit-maps in its 1Mbyte memory. Its maker, GRiD Computer Systems, believes it to be unique.

The machine is waterproof and fairly rugged (it will survive being dropped) and was designed to be used like a clipboard. But it also has a nine-pin serial port, so can collect data automatically from electronic instruments.

Richard Trainer, of Loughborough-based Tangent Technology Designs (TTD), thought it would be ideal for collecting data from theodolites, which are used extensively by archaeologists. A survey must be done as a site is excavated, mainly to record unexcavated conditions to show where the excavation is to be done. After a dig, the soil is replaced carefully or, more often, the hole is filled with foundations for a building and it is difficult to see where the dig took place.

Theodolites are set up at reference points related to grid references. They measure two angles and a height is measured with a marked staff; from this, the distance of test points can be worked out by trigonometry. Nowadays, some projects use electronic distance measurers (EDMs), which eliminate one of the measurements and one of the calculations. The lucky few have combined electronic theodolites and EDMs.

But frequently, in archaeology, that is where the technology stops and the long-suffering people doing the survey must write down the raw data by hand and calculate the coordinates of the test point later. Waterproof paper is used when it rains!

Fortunate ones, on better-funded projects, have been using Psion Organisers or Husky Hunters in the field with their electronic theodolites and EDMs. The Psion, a very small, simple, hand-held computer, costs around £80 and is used like a programmable calculator: you tap in the raw data by hand, whereupon it calculates 3D coordinates and stores them. The Husky Hunter, a larger and more sophisticated hand-held computer, can download data from an electronic theodolite and store the raw data as well as the coordinates. These systems represent the first stage of automation.

Map generation

A big problem with both the Psion and the Husky Hunter is that they generate coordinates, not a map. Even skilled archaeologists admit that it's easy to record particular points wrongly and even to enter the wrong setup data at the beginning of the day, without finding out until the coordinates have been plotted.

But the program written by TTD for the Gridpad plots a map on its screen as the raw data is collected, so it is much easier to spot mistakes as they are made. This feature is important because virtually all archaeology is destructive; digging is a once-only exercise. And there is never enough time for a dig, so anything that saves time is to be welcomed.

Only the edges of features are surveyed, such as the outline of a stone pavement. Using conventional methods, the survey coordinates are plotted onto a dimensionally stable plastic film called Permatrace. Then details such as individual paving stones are drawn on by hand. These must then be digitised if the map is to be stored on a computer — work which is usually saved for the winter. But because the Gridpad has a digitising screen, drawings can be done on the screen, which automatically digitises them.

Trainer said "If you take the Pad on site, you don't need to digitise. By the time the site has been excavated, all the data will have been digitised." One tenth of the York Archaeological Trust's post-excavation staff are currently employed in digitising — a significant expense.

GRiDPad's screen, showing a map of a tumulus, with contours.

If any surveying has been done in the past, this data can be loaded into the Pad at the start of the survey to avoid repetition. TTD software also allows zooming in and out and panning and can glue together the work done by two people on adjacent areas of a site. "It's like taking a cad package out with you," said Trainer.

A rather more glamorous aspect of archaeology than surveying is finds — the items recovered from the excavation, which fall into two categories: bulk finds, such as pottery sherds, flint and bone; and small finds, which are usually the interesting things such as jewellery and coins.

The only record made of most bulk finds is in which layer of earth they were found, since the conventional method of recording a small find is to survey its position in the ground and then to put it in a marked plastic bag for cleaning and cataloguing.

With the Pad and TTD's software, the position of a small find can e marked directly onto the map shown on the Pad's screen, using the brass stylus. Then a description can be written onto the screen, which is stored in a file associated with the point on the map.

The advantage of all these time-saving

Raw data is entered by means of a stylus and is then digitised as the work proceeds. GRiDPad then plots a map of the dig on screen.

While it is difficult to raise money for a dig (and harder still in a recession, when little property development is going on), the post-excavation funds which usually finance the map-making stage are even more scarce. Post-excavation work is as important as the dig itself; if the dig is not published, it is worse than not digging at all, as digging is destructive.

Andy Copp of York University is a supervisor at Sutton Hoo, in Suffolk, at the site of the famous Saxon ship burial and associated cemetery. He commented: "At the moment, we may be recording the minimum amount of necessary information [during an excavation]." If it took less time to process the information collected, archaeologists would be able to gather more evidence about the past.

Copp also pointed out that faster processing of the data might allow archaeologists "to take the work one stage further and draw reconstructions of buildings. This would involve both [site] plans and the finds to see if you could, for example, identify post-holes which belong to the same building. You could use AutoCAD".

The beautiful, sophisticated reconstructions seen on the *Down To Earth* programme were produced by an alternative to AutoCAD—3D animation. Imagic, a TV graphics animation house, used Soft Image software running on Silicon Graphics' Iris workstations to give the viewer the impression of, for example, walking around a reconstructed house. This technique could be the next development in archaeology: IMAGIC is working on a couple of projects commissioned directly by archaeologists.

50 000 points

Trainer is not an archaeologist himself, but a software engineer. He spent about a year and a half writing the code for the GRidPad in C and Pascal, with advice from archaeologists, one of whom is his wife. He estimates that the Pad can store the equivalent of more than 50,000 points. "It would be hard to make more than 1,500 measurements in a day, so the Pad could store about a month's work," he said, though he expected most people to download their data to a host computer at the end of every day.

Trainer said some archaeologists have bought laptop computers for use on site, but they are rather delicate, not waterproof and could easily run out of battery power before the end of the day.

One of the major reasons that it is taking so long to automate archaeology, of course, is cost. Most projects set money aside for EDMs and computing resources, but will they be persuaded to part with money for the Gridpad? The Pad and software cost around £3,000 together and a suitable theodolite and EDM, such as Zeiss's Elta 6 Total Station, is about £8,000. Total Station is much more accurate (to 3mm over lkm) than necessary for this type of equipment, but it is comparatively simple for an electronic theodolite.

The TTD and Total Station system was designed to be easy to use. "It takes about a day to learn," claimed Trainer. "It prevents a lot of mistakes because you can see what you're doing and there are pull-down menus and help messages." Gridpad may be able to help archaeologists over the computer phobia which many of them suffer from, but Trainer warned that the Pad could introduce problems not seen before: "Essentially we are getting rid of paper and that produces phobias."

Data on site

So far, the system has been tried out in Israel and Gloucester. At Tel Jezreel in Israel, the British School of Archaeology in Jerusalem and Haifa University are working together on a large and complex excavation. The site measures 200m by 600m; it is mainly iron age, with a palace built by Jezreel, who is mentioned in the Bible, and includes a chalcolithic village (from the fifth millenium BC) and a church and village built by the Crusaders. "Gridpad made the work much easier," says Trainer. "We surveyed the site in three days; it would have taken months without the EDM, Pad and software."

Gloucester City Council's assistant archaeology director, Malcolm Atkin, has used an early version of the system to build up a contour survey at two sites. One was the Norman castle in the city — a rather confined urban site. The other, in contrast, was in the countryside, plotting areas where a magnetometer was to be used.

Atkin said that on the latter site everything could be done from one position, so the archaeologists didn't have to wander all over the fields with tape measures. But he said the main advantage of the system was its speed: "We're always under pressure of time and we need absolute accuracy. It will make an enormous difference to our work."

An electronic clipboard is probably the most accurate description of the GRiDPad. It is about the size of an A4 pad, with a screen about A5 size and looks like an Etch-a-Sketch. A brass stylus, attached to the Pad by a wire, is used to enter data, text or sketches simply by writing on the screen.

Liquid crystal "ink" appears where the stylus has been; any mistakes can be crossed out with a vertical line, whereupon they disappear and the correction is written instead. The stylus acts as a mouse too, when it is tapped gently on the screen.

The screen itself is made of two layers, a conventional LC screen and a layer which detects the position of the stylus. This upper layer consists of glass with an undulating surface and a conducting compound, antimony oxide, in the "valleys"; when the stylus touches the screen it completes a circuit. To detect its position, 5V is applied across the screen horizontally, then vertically. GRiD says the screen is difficult to scratch and should not wear out.

The Pad can recognise handwriting in the form of block capitals and numbers, even if they touch; if a character is unclear, the software will choose the most likely one. GRiD says some users have to alter their handwriting a little to help the Pad along.

It converts handwritten symbols to Ascii characters, using a combination of two methods, segment-then-recognise and recognise- then-combine. In the first, the computer combines the strokes that go to make up a character and recognises the whole character at once. In the second method, the computer identifies strokes as they are written and gradually builds up a picture of which character is intended. The technique used here is called elastic matching.

Jeff Hawkins, an ex-neural biologist who designed the algorithms for the GRiDPad, said it "works on one character at a time. But the algorithm is so fast that we take a guess at the character and try to match it with a template, grouping several strokes together."

At the heart of the Pad is a standard PC-compatible with an 80C86 processor running at 10MHz and 1Mbyte of system ram, and it can be converted to an ordinary laptop machine by plugging in a keyboard and monitor. It can be programmed like this, or programs can be loaded via an RS-232C 9-pin serial port and the LapLink program stored in rom. Instead of floppy disks it has two removable lMbyte ram cards. The screen has a resolution of 640x400 for both display and pen position sensing, which is marginally coarser than VGA.

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CIRCLE NO. 139 ON REPLY CARD

THE SILICON TRAIL STARTS HERE

IC design can be implemented in silicon in a variety of ways. Nigel Howell explains the pros and cons of different approaches.

There are three basic strategies available to execute an IC design in silicon: the programmable logic device (PLD), the full custom device, and the application specific IC (asic).

Taking the PLD first, this relies on eprom technology and is implemented using a matrix of logic gates. As each device has to be programmed individually and for large numbers of latches, this method is unpractical and expensive.

Also, because the internal silicon layout is fixed, gate utilisation is limited and so less circuitry can be accommodated on a single device.

Another approach, at the other extreme of the spectrum, is a full custom device. Each design is hand-crafted to optimise silicon use and hence improve speed.

But these devices take a long time to design, due to complexity, and hence are costly to produce. To be cost-effective, manufacturing volumes must be high to cover initial design and tooling costs.

A trade off between these two options is the semi-custom asic which combines the complexity of a full custom IC with the simplicity of a programmable design.

For asics, software has been developed to enable a unique design to be produced out of a library of gates, with the possibility of fairly cheap manufacture in low volumes and the capability for reasonably complex design.

Two sorts of asic

There are two main asic categories from which a designer can choose — the gate array or the standard cell.

A gate array is manufactured on a master silicon wafer which contains a matrix of logic devices. All the designer does is connect these logic gates together in a unique pattern.

In this way the master wafers of logic gates can be mass produced beforehand and customisation is only completed at the final stage of production. Production costs are reduced and there is a faster turnround in device completion.

But this solution does have a drawback in that there are many redundant logic gates because the design routeing can only occur along fixed channels. Silicon (and money) is wasted as a result and the performance of the device is limited.

Standard cell

The alternative approach is to use the standard cell, where the full asic design is constructed from predefined building blocks which have been tested beforehand by the manufacturer. Designers simply select the combination of blocks required and connect them together.

Advantages are that because each block has been previously tested, there is a high probability that the completed design will work first time. Also less silicon is used because there are no areas of redundant silicon.

However, tooling charges are more expensive because a full mask set is required in production.

The cost of producing a customised silicon circuit is dependent on which of the technologies is used (**Table 1**) and how many devices are required.

Obviously, for low volume batches, the PLD solution would be the most cost-effective since it entails little initial cost layout on production and only incurs costs at the programming stage for high volumes.

However, a lot of CPU time will be needed and this could prove expensive.

There is little to choose between gate arrays and standard cells. But due to the initial costs of tooling, the gate array method is slightly cheaper for lower volumes and as the volume increases, less redundant silicon makes the cost of standard cells more competitive, until it becomes the cheapest method.

If a design has been proven and it has been shown that there is a market for high volume production, then in the long-term it may be cost-effective to produce a full custom IC.

Advantages of this approach are that less silicon will be used, and the speed of the device will increase accordingly.

Table 1. Comparing the route to silicon

parameter	PLD	Gate array	Standard cell	Full custom
No of gates (complexity)	102	103	103	103
Design time (years)	2	4-13	6-26	1-2
Manufacture time (weeks)	0	1-8	6-12	8-16
Practical "call off" volumes	1-10,000	5000-50,000	50,000-200,000	200,000+
Circuit	Reasonable	Good	Very Good	Excellent

Once the mask-set for production has been fabricated, manufacturing of devices will be fairly cheap and the pros of this method will outweigh the cons.

Non-recurring engineering

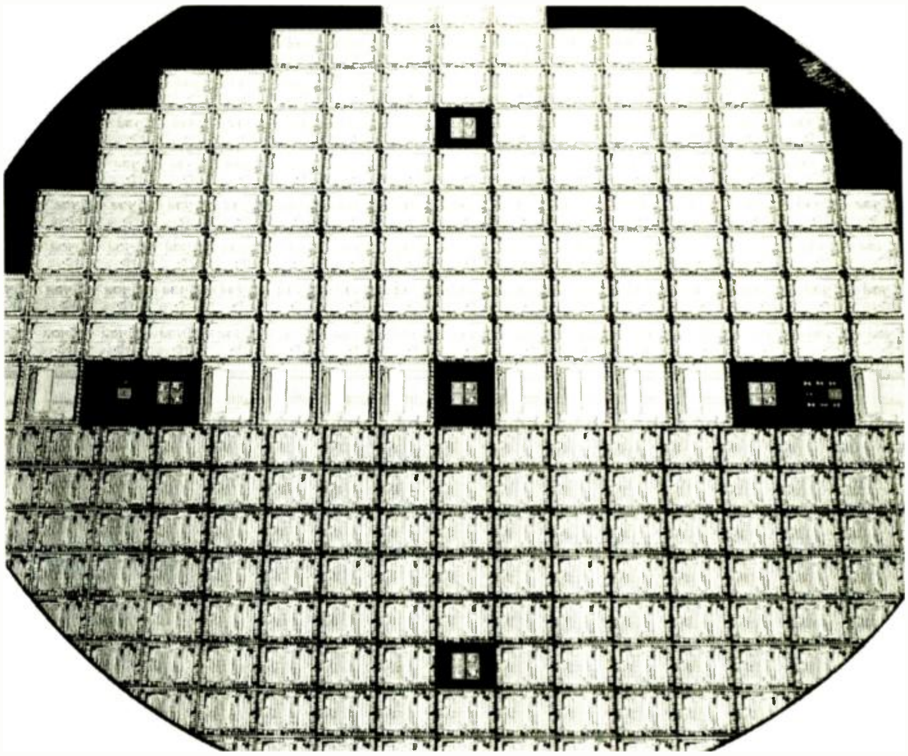
A parameter not yet considered when deciding which route to silicon to take is the non-recurring engineering (NRE) charge. NRE is a charge made at the outset of production, which covers technical support, tooling and mask manufacture. It cannot be avoided in asic and so must be considered.

The only time it is reduced to zero is when the PLD option is used.

For gate-array, standard-cell and full custom options, the NRE charges roughly vary 1:20:100 in proportion, respectively, reinforcing the opinion that full custom is only really viable for high volume manufacture.

NRE charge also varies depending on the point that the customer enters the design process.

As asics are becoming cheaper and more complex with the advance of technology, companies are beginning to choose them as a low risk method of committing a design to silicon.



Suppliers such as Micro Circuit Engineering can offer a low-volume prototype at relatively low cost.

Differing customer involvement

Once the decision has been made to produce a design using asic there are five basic levels at which the customer may enter the production process (**Fig. 1**) though these options may not apply to all manufacturers.

Level 1: the customer merely supplies the manufacturer with a specification and the rest of the work will be carried out on his behalf, from circuit design through to prototype production.

Level 2: the circuit diagram and specification are prepared by the customer and the rest of the process is completed by the manufacturer—from schematic capture to prototype production. Schematic capture is the process of transferring the circuit diagram onto a software database, using one of the packages discussed later, such as Idea by Mentor Graphics. This is then used during manufacture.

Level 3: At this level the schematic capture and simulation is performed on an acceptable cad system-engineering workstation and the schematic files and simulation listings are given to the manufacturer to complete the process.

Level 4: the customer must not only complete all the previous tasks but also perform the design verification on a powerful computer such as a Digital Vax. By entering at this level, the NRE charges would be reduced and the overall costs reduced.

Level 5: silicon layout is performed, leaving only the actual production to complete.

Some companies allow less points at which the customer may enter the design process, others more.

Some companies may be involved only in the design process, some only in manufacture.

For example, Rapid Silicon is a company that will produce an asic design solution to a specification given by a customer but will not fabricate the design, only helping with its creation.

In other words, Rapid will perform the tasks outlined between levels one to five but will not produce the physical integrated circuit.

For this final stage the company will help select a suitable silicon vendor and arrange to have it produced. Rapid will design the circuit on one of a choice of computer-aided design packages developed especially for this purpose.

Suitable design packages

Manufacturers supply a list of packages that are suitable for their design process and also a library of available functions. Some packages are shown in

It would be too lengthy to discuss each of these systems' merits and faults, so I will explain briefly the facilities generally available,

Mentor Graphics's Idea system can be used as an example. Mentor Graphics is an American Company who claim to be the largest supplier to the industry.

Idea has the ability to create a schemat-

Table 2. Suppliers of design packages

Workview
Viewlogic Systems Inc

Scald
Valid Logic Systems Inc

Logician
Daisy Systems Corporation

Sunews
Sun Microsystems

Dash
Future Net Corporation

Orcad
Orcad Systems Corporation

Design Engineer
Intergraph Ltd

Phase 182
Integrated Silicon Design

BX
MCE Idea Mentor Graphics

ic and also simulate its use. Sample pulses and waveforms are displayed simultaneously on the same screen. The package is menu driven based on hierarchical methods and is, as most are, devised around the edif (electronic design interchange format).

Schematics can be entered in Boolean, programming language or diagrammatical format for good flexibility and the package has the ability to incorporate libraries of functions supplied by silicon vendors to allow it to be made specifically compatible with that vendor.

Though the exact forms vary, these features appear on most packages.

Final stages

Once the design has been produced by this means it must be verified using a more powerful computer such as a Vax, Mach-1000 or Hichip simulator. Autoplacement and routeing procedures required before production can begin will also be carried out at this stage.

Finally, the software design can be manufactured using advanced production systems. It is becoming possible t produce several different designs on a single silicon wafer, reducing the cost of producing a custom chip, as several companies can share the production costs for one wafer (in very low volume fabrication).

The European electron beam (E-beam) system used by Texas Instruments is an example of how the multi-design wafer is produced.

A wafer can be manufactured without a mask set. But this can only be used for low volumes, because of the time factor and as volume increases, a mask set must be produced.

There are about 300 silicon foundries worldwide — a list of those available in Britain (**Table 3**) is published by the DTI. Micro Circuit Engineering, a supplier from Tewkesbury, offers a low-volume prototype service at a relatively low cost. It produces the physical prototype as a gate array in a turnround time of four weeks.

Editorial survey: use the information card to evaluate this article. Item E

Table 3 principal UK manufacturers

Hitachi
Watford, Hertfordshire, WD1 7TB

Intel Corp
Swindon, Wiltshire, SN3 1RJ

International Microcircuits
Alencon link, Basingstoke, Hants, RG21 1RD

MCE
Ashchurch, Tewkesbury, Glos., LG20 8TB

Motorola
Aylesbury, Bucks, HP20 2NF

National
Horne Lane, Bedford, MK40 1TR

NEC
Linfordwood Business Centre, Milton Keynes, MK14 6NP

Texas Instruments
Bedford, MK41 7PA

Finally... an exceptional PCB and Schematic CAD system for every electronics engineer!

BoardMaker 1 is a powerful software tool which provides a convenient and professional method of drawing your schematics and designing your printed circuit boards, in one remarkably easy to use package. Engineers worldwide have discovered that it provides an unparalleled price performance advantage over other PC- based systems.

BoardMaker 1 is exceptionally easy to use - its sensible user interface allows you to use the cursor keys, mouse or direct keyboard commands to start designing a PCB or schematic within about half an hour of opening the box.

HIGHLIGHTS

Hardware:

- IBM PC, XT, AT or 100% compatible.
- MSDOS 3.x.
- 640K bytes system memory.
- HGA, CGA, MCGA, EGA or VGA display.
- Microsoft or compatible mouse recommended.

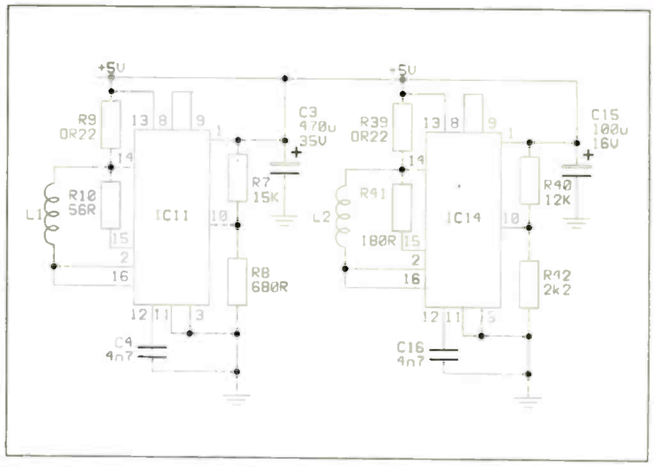
Capabilities :

- Integrated PCB and schematic editor.
- 8 tracking layers, 2 silk screen layers.
- Maximum board or schematic size - 17 x 17 inches.
- 2000 components per layout. Symbols can be moved, rotated, repeated and mirrored.
- User definable symbol and macro library facilities including a symbol library editor.
- Graphical library browse facility.
- Design rule checking (DRC)- checks the clearances between items on the board.
- Real-time DRC display - when placing tracks you can see a continuous graphical display of the design rules set.
- Placement grid - Separate visible and snap grid - 7 placement grids in the range 2 thou to 0.1 inch.
- Auto via - vias are automatically placed when you switch layers - layer pairs can be assigned by the user.
- Blocks - groups of tracks, pads, symbols and text can be block manipulated using repeat, move, rotate and mirroring commands. Connectivity can be maintained if required.
- SMD - full surface mount components and facilities are catered for, including the use of the same SMD library symbols on both sides of the board.
- Circles - Arcs and circles up to the maximum board size can be drawn. These can be used to generate rounded track corners.
- Ground plane support - areas of copper can be filled to provide a ground plane or large copper area. This will automatically flow around any existing tracks and pads respecting design rules.

Output drivers :

- Dot matrix printer.
- Compensated laser printer.
- PostScript output.
- Penplotter driver (HPGL or DMPL).
- Photoplot (Gerber) output.
- NC (ASCII Excellon) drill output.

All trade marks acknowledged



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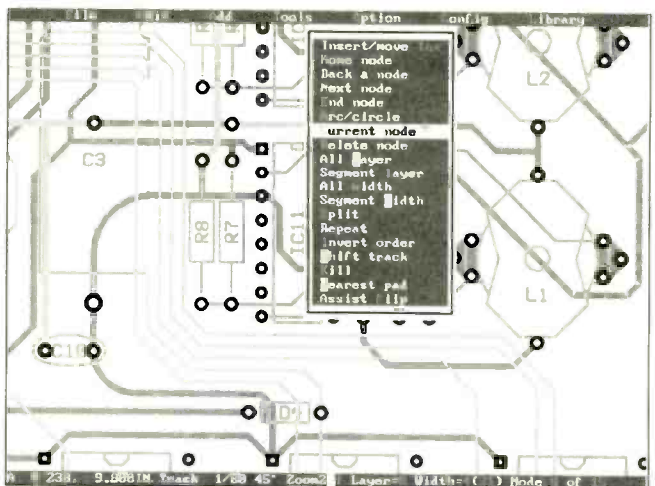

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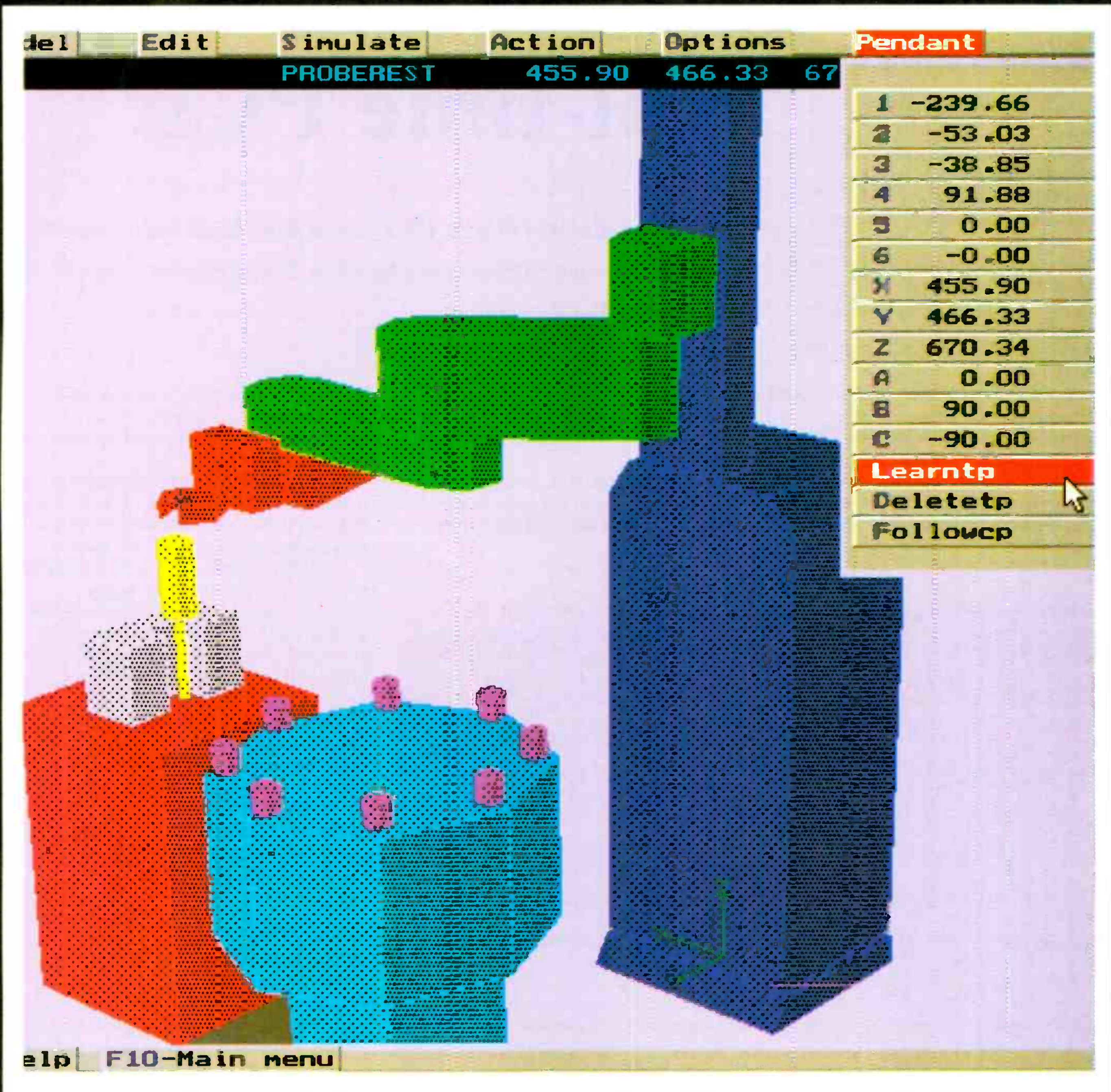
pc engineering



Simulation is an indispensable tool for planning all manner of systems, and Robotics is no exception. Workspace from Robot Simulations of Newcastle runs on a PC and allowing engineers to evaluate different robots, experiment with designs of factory workcells or calculate cycle times.

Virtual instruments reviewed
Real-time PC operating systems

OS-9000: real chance for real-time PCs?

Lack of a real-time OS for the PC has held back industrial application, but Microware's Stephen Montgomery says OS-9000 will change all that.

PC use in industry and science has never really managed to match its widespread popularity in the business community, primarily because of the limited availability of a low cost true real-time operating system.

But now a new real-time multi-tasking operating system is available for the 386 PC and single-board computers, combining many of the individual advantages and benefits of several operating systems in a single modular package.

Microware's OS-9000 real-time operating system, modelled on the OS-9 operating system, brings VME-style, real-time system software to the PC and to the embedded 80386 microprocessor CPU.

It will allow the carrying out of more than one task at a time — in real-time — and will address the whole 4Gbyte memory range as a single contiguous block, giving access to more than 640K without resorting to inelegant techniques such as block switching (OS/2 can also do this - see box).

One of the major shortcomings of dos is its inability to address more than 1Mbyte of memory in "real-mode". But OS-9000's true 32-bit addressing can access the full 4Gbyte and increase practical program size above 450 - 500K.

Coupled with multi-tasking, OS-9000 offers the PC user another enhancement over the crop of windows packages currently available; that of multi-user capability.

Most of the time a PC is idle, waiting for external input in the form of operator interaction or line response from hardware. Mainframe users are familiar with multi-user environments and their processors are utilised at a far greater percentage level.

Dos supports multiple monitors, since it makes the video memory start-addresses generally unique, but that is only in single-application, single-user mode.

Combine multi-tasking with the ability to communicate efficiently with more than one video terminal and a multi-user system results. This is made even more effective by the re-entrant characteristic of OS-9000 modules, which reduces memory requirements.

A further advantage is that several users sharing one machine also share the same data locally, so individual machines do not have to be networked together.

OS-9000 can be loaded into a standard 386 PC-AT, replacing dos and instantly providing a large number of performance benefits and opening up the power of the 80386 microprocessor.

It can be ported onto any circuit containing an 80386 microprocessor, with the same modules and application program that would run on the PC, simply by altering the device drivers and device descriptors to match the target hardware.

This is significant where larger companies, such as British Telecom, design-in the 80386 in massive quantities.

But the most appealing benefit is in providing real-time, multi-user, multi-tasking capability on the PC, something VME users have been familiar with for

CURRENT PC SYSTEMS

At present the designer is faced with a handful of choices of real-time operating systems to run on the 386 PC.

The largest name in the sector is Intel who make the 386 chip and its iRMX operating system can be configured to run on the PC-AT. The system is fast, offering interrupt latency times down to 7μs and task switching times of about 13μs and has a degree of memory protection where each call is checked to ensure that memory assigned to other tasks is not corrupted.

It runs with a pre-emptive, priority driven scheduler and can address the full 4Gbyte space of the processor. But it is, however, expensive, complex to use and unable to run dos as a task.

Microsoft entered the PC multi-tasking and windowing market with two products; OS/2 and Windows.

OS/2 is a multi-tasking system with pre-emptive scheduling and high performance file system. It has shown enormous potential as a replacement for dos and is favoured by a number of programmers.

But it has not been accepted in the market and now even Microsoft is determined to see it dead and buried by concentrating on the dos related windowing package - Windows 3.0.

Windows 3.0 is the company's latest offering which is in fact more of a graphical user interface (GUI) than a multi-tasking operating system, claiming no real-time capability.

Other operating systems for the 80 x 86 family exist in both PC and stand-alone form, each providing specialised features.

Some of them provide just a fast kernel — basically a library of system calls that are linked in to provide basic task scheduling.

Others provide full-blown operating system capability and development environments along the lines of OS/2 and iRMX. Yet more sit in the middle.

Such names as Flexos from Digital Research, QNX, LynxOS and Desqview fall into these categories and suit particular applications.

years. The capability is performed in real-time and is achieved by controlling the execution of tasks with a kernel which implements task switching and interprocess communication.

Execution time is assigned to tasks, in round-robin fashion by time-slicing.

Unlike Microsoft Windows, CPU time is assigned rather than supervised and so tasks do not have to relinquish the CPU of their own volition. In this way true multi-tasking is possible rather than a simple sharing of the processor.

Various refinements allow tuning of the execution cycle to weight CPU attention in favour of the most critical and important processes and tasks may not be run at all if their status is sleeping, suspension or waiting.

Interprocess communication mechanisms provide a powerful and versatile choice of methods for passing data between processes, whether single bits or large blocks of data (and all the steps between), and for synchronising the execution of separate tasks.

Fundamental to implementation of real-time systems is priority-based preemptive task switching (the system designer can designate tasks as high priorities that must execute immediately they become active, replacing the currently executing task which loses the remainder of its time slice).

OS-9000 supports this facility.

It also supports a wide range of PC hardware and peripheral devices; ESDI and SCSI disks and tape, PC floppy disk, graphics, serial and parallel I/O and networking.

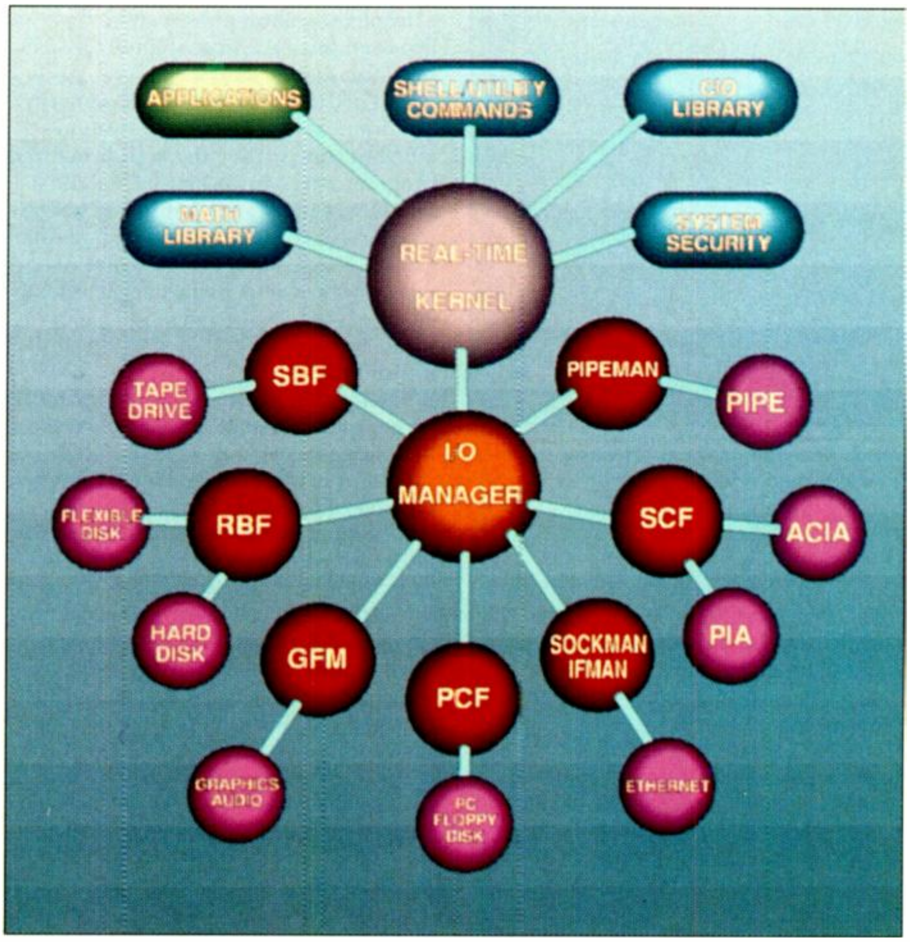


Fig. 1. Modular architecture of the OS-9000 operating system

Modularity

System designers do not always use all the hardware in a particular project: so why should they load the full suite of operating system software? OS-9000 is built of optional modules, each one re-entrant, so that only one copy is required to support a number of similar devices.

Core of the operating system (**Fig. 1.**) is the real-time kernel which controls scheduling of tasks and handles ancillary services such as memory management and inter-process communication.

The versatile, unified, hardware independent I/O system, able to be customised and extended to suit application, comprises an I/O manager, file managers and device drivers which process I/O service requests at different levels.

Because of re-entrancy, just one copy of the I/O manager is required on the system, one copy of each file manager for each class of device (disk, tape etc.) and one device driver for each type of device.

A separate device descriptor, containing specific I/O device details, is necessary for each individual unit. But if a device driver does not exist for a piece of hardware, a new driver can be quickly written in C from scratch or based on an existing one.

An additional feature of the system is that modules can be installed and removed dynamically while the system is running — an aid to system revision and testing — perhaps where network calls can be made to disk for proving, and then to the actual network.

All memory modules, position-independent and run-time locatable, contain a header detailing type of module, its revision number, and other information. The system automatically checks the revision numbers and uses the latest, simplifying development ensuring that the intended version is used.

Graphics under OS-9000

Graphics support is available with rave (real-time audio/visual environment), a multimedia development tool and user-interface that greatly simplifies design of realistic man/machine interfaces for real-time process control systems. It combines high quality audio and video, computer generated graphics and customised menus in the same user interface and so allows real-world stimuli to be incorporated into a control system. The method results in a more intuitive interface requiring less operator "brain power" and consequently improving accuracy and safety of a system.

Development support contained within the rave package allows use of cameras, microphones and PC paint packages at a level easily understood by graphics artists and industrial psycholo-

Fig.2. Real-time audio environment (rave) operating under OS-9000 on a PC

gists. It also releases software engineers from the task of MMI screen design — a task that can be time-consuming, laborious and unappealing.

Networking

As far as networking goes Ethernet, based predominantly on the National Semiconductor chipset, is the prime communication medium with TCP/IP serving as the main protocol.

OS-9000 supports this type of networking with the Internet dedicated file manager which again is installed in a system only as required, providing a BSD4.3 Unix socket-style interface to the TCP/IP protocols.

Development environment

OS-9000 provides a complete range of resident and cross-development tools covering languages. C is currently available, with others planned for future release and a macro assembler is also available. Other tools include debuggers for system-state and C source-level debugging; and a screen oriented text editor.

OS-9, the equivalent Motorola based operating system, is supported by several hundred hardware and software products and this is expected to happen to OS-9000, resulting in an extensive range of packages.

With OS-9000, the operating system installed to run the application is the same as the one used to develop under. When development is complete, the tools are stripped off, leaving the bare operating system together with the application code.

Implementation phase can be bypassed since the final solution grows from the start by addition of new modules. This, together with the modularity requirements of the system, promotes efficient code writing through structured programming. An additional benefit is that tools can be loaded into any system temporarily for field testing and modification — extending to rom-based systems where even debuggers can be loaded for testing the system.

Beyond the PC

While the 386 PC is eminently capable of running the software, it may not be the final target.

Cost or reliability reasons may dictate transfer of the developed application onto a stand-alone, custom-designed single board computer. At this stage it is a straightforward task to port OS-9000 and the application code onto a suitable custom board for final delivery. The main work required will then be in replacing the device drivers and descriptors for the changed hardware and producing the boot rom to configure the system at start-up (not necessary if the same hardware is used or the system does not require any peripheral hardware).

Applications

Typical applications where real-time multi-tasking is required include process control, industrial control of plants, data logging and communication, measurement of processes etc., intelligent products such as point-of-sale terminals and weighing machines.

A typical application is where several types of plant monitoring equipment are coupled together with a multiple-stage manufacturing process in a complicated machinery/assembly operation, for example in a paper mill in a classical real-time application.

Sensors monitor the moisture content, tension, thickness and weight of the paper as it passes through the wet and dry processes and cause adjustments to be made in process flow speed, pulping rate, water addition and drying temperature.

Use of a single controller will reduce the possibility of problems occurring between different intelligent machines due to complexity of several separate sensor/controller processors.

Basing the whole system on one machine will not only allow greater optimisation to be achieved for production rates but will simplify implementation of fail-safe and back-up mechanisms since data on the whole system is held locally in one machine and can be duplicated relatively simply.

Production data and operating history is then easily fed to a background database for process evaluation.

A more horizontal application of an operating system of this type is illustrated by a large point-of-sale terminal manufacturer.

Here the application criterion is not so much for enormous processing capability as commonality of equipment across several product ranges.

By standardising on one multipurpose operating system, hardware and software developments are extended across the products by a central core of designers with access to a single library of code modules. As a result once a device driver, for instance, is written it can be used again and again in different circumstances without the duplication of effort that would result if different operating systems had been employed.

The future

So where will OS-9000 be when everybody has outgrown the 386 and moved on to the 486 and eventually the 586? As it is written almost entirely in C, allowing quick porting to new processors the answer should be right there with them.

Not only that, but if the 386 is not powerful enough for a particular application, code already designed can be transported to another processor with only minor modification and a recompilation. At present this can be toward the 32-bit Motorola 68020, 30 or 40; but will shortly be toward the 88000 risc chip.

Portability provides a highly appealing design option; the operating system can be selected and application code written before the final choice of processor is made — and that could be a standard PC or a custom single-board computer containing one of a number of cisc or risc devices.

With so many advantages over the current PC operating systems I believe OS-9000 is set to become the real-time operating system of the future, and will open up use of the PC to a whole new range of real-time applications.

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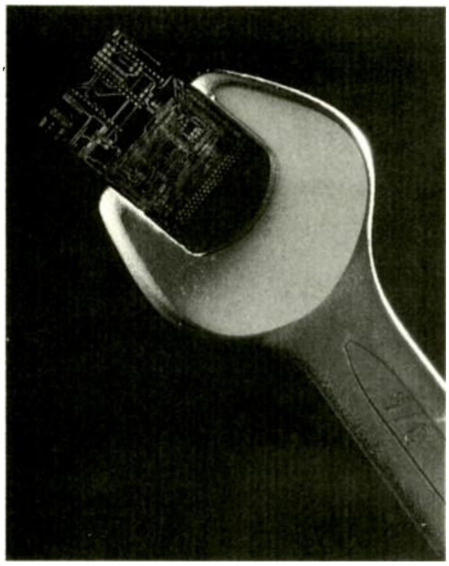


Simulating the system

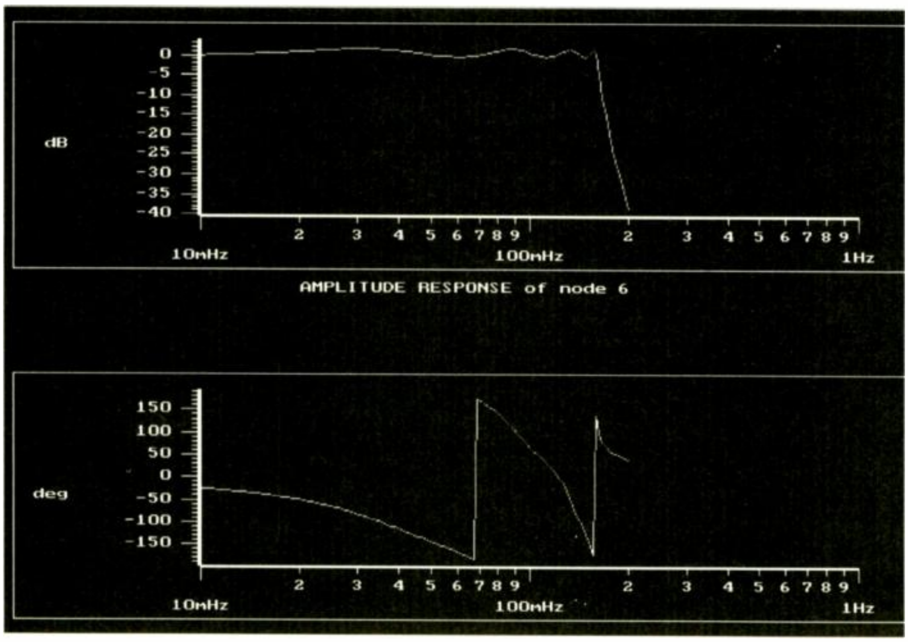
Maxsim is designed to model and analyse the performance of systems in frequency and time domains. John Anderson tries it out and explains his reservations

Maxsim is a simulation system providing performance analysis in both the frequency and time domains. The modelling system relies on describing the format of the various system blocks in a simple Ascii file, which is then interpreted, checked and simulated.

Program installation

Software is supplied on a single disk, together with a thick, spiral-bound, photocopied manual. The software comprises the single application file, a number of example files and a few graphics files. An install file copies the program to your hard disk, though you could do this yourself; there is no copy protection. Rather strangely, the latest version of Maxsim insists that the program should reside in a different directory to the data files so, if you copy the files across yourself, follow the instructions carefully.

Bode plot for 8th order Chebychev low-pass filter.



Maxsim is written in Turbo Pascal with auto screen-sensing facility, allowing it to be used with a number of popular screen standards.

Entry of the transfer function

Typing Maxsim executes the program. After the sign-on message, you can select the file to be simulated from the files with the extension .DAT. Once the file has been selected, the program moves to a simple Ascii editor to give you the chance to set up the system for simulation. An example is shown in the box.

When the system file has been set up, the program checks the formulation for errors of syntax. There may be some errors which cannot be detected until the system calculation routine, which may then cause the program to abort.

Frequency simulation

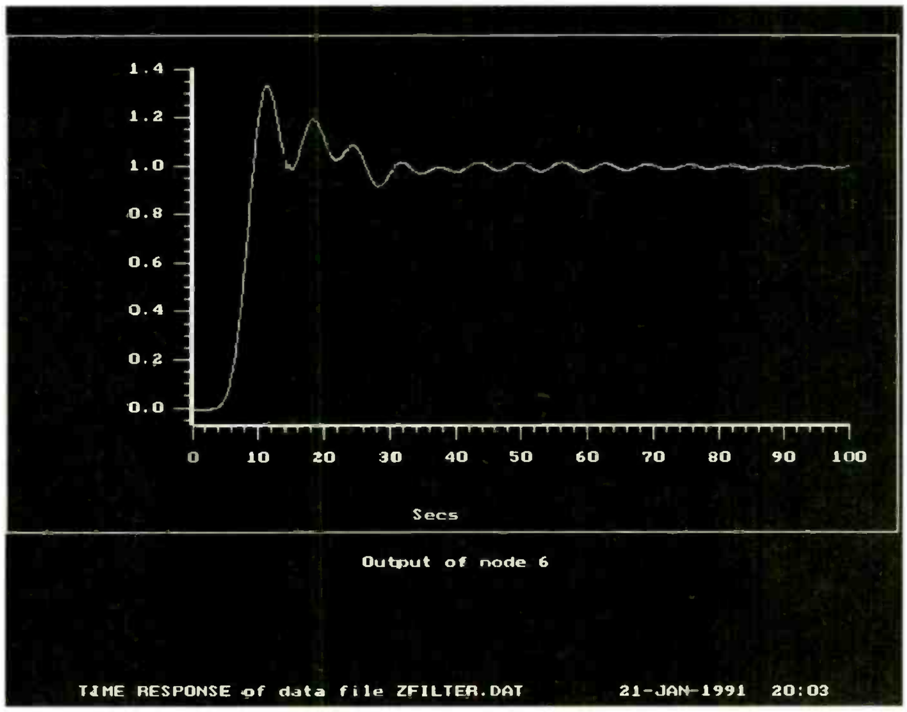
In the frequency domain, magnitude and phase information is derived from either automatic or user-defined frequency range and increment. This process was quite slow, taking several seconds to produce the data set on a 8MHz AT. Once generated, the data may be displayed as any one of the Bode, Nyquist, inverse Nyquist or Nichols charts. As all the data is available at this stage, screen plotting is fast.

Time simulation

A reduced subset of the built-in components may be simulated in the time domain. Why capacitors and inductors are excluded from this is not clear, since it obviously limits the use of the package when compared to other performance simulators such as Spice. Time simulation follows the same procedure as for the frequency simulation, the steps of the time simulation slowly accumulating until the dataset is complete, at which

SIMULATION MODELS

General system models
Integrator, simple gain, adder, second-order phase shifter, sampler, pure time delay, multiplier, divider, phase shift.
In time domain
Limit, backlash, friction, dead zone, noise generator, digital filter, stiction, switch.
In frequency domain
Resistors, capacitors, inductors, voltage amplifiers, mutual conductance, transformer, delay line, operational amplifier, transistor, fet.
Stimuli
Frequency: frequency sweep, linear, log or spot frequencies.
Time: step, ramp, square, triangle and sine wave, or from a user- specified 50-point curve.



Time response for 8th order Chebychev low-pass filter.

The editing environment

point it may be plotted.

An interesting option is to be able to set the type of numerical integration used in the simulation, from rectangular and trapezoidal to a fourth-order Adams Bashforth. It is not clear why an engineer would want to do this, but it could prove useful in the teaching environment, where the sensitivity of the various algorithms to step length could be conveniently demonstrated.

A wide range of input stimuli is available for the time-domain simulation, including step, pulse, ramp, sine, triangle and user-defined functions, defined by data. In the time domain, the input driving function can be defined by the user in a file arranged as a table of up to 50 values, stored as two columns. The first values are the increasing time samples and the second values are the corresponding function amplitudes.

Examples and help

Examples of electronic, mechanical and multi-loop control systems are presented to give a sound base for simulating your own system. The help system, although context sensitive, is very limited and gives little assistance. An indication of this is that the route out of the program is not properly sign-posted. It turned out that, at one particular level, the user must press the "Q" key, which is fine once you know, but the exit from any program should be a simple matter. The help facility within the editor was rather better and included examples of data file layout and syntax. However, there was a bug in the program which prevented invoking the help system within the editor a second time.

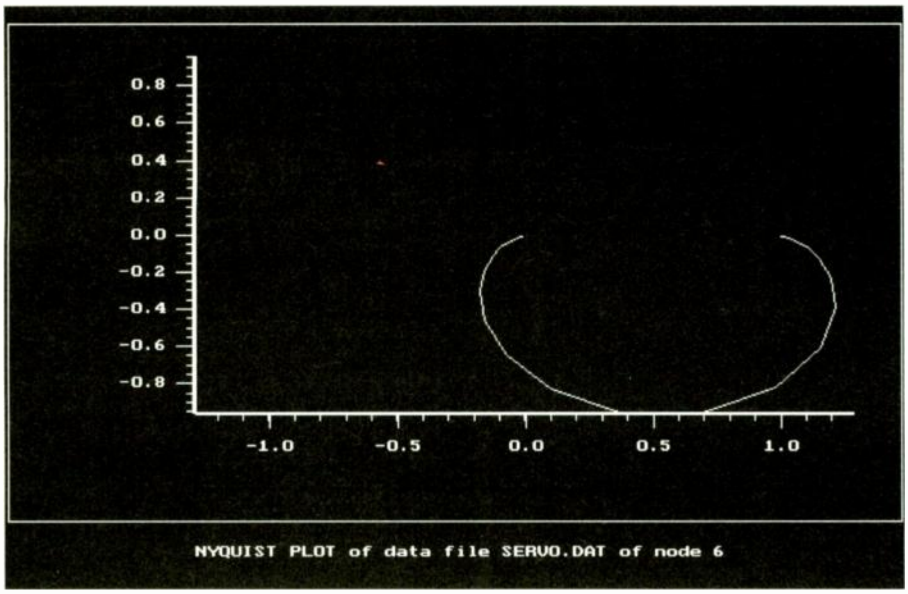
HARDWARE NEEDS

Minimum is a PC or PC-AT running MS-DOS version 3.0 or later. CGA, EGA, VGA or Hercules graphics card.
Optional Epson-compatible printer, HP plotter or HP-compatible laser printer.

Using Maxsim

The program can handle systems of up to 50 nodes per sub-system and of up to 50 sub-systems per node. As the program was rather slow even with the modest systems provided in the demonstration set, it is likely that large systems at the limit of what can be handled with this program will take many hours to run.

Once the rather strange user interface was mastered, the generation and testing of complicated systems was accomplished in short order. However, there were a number of occasions where the data provided to the program by this novice user was not wholly sensible, and the program handled this in the worst possible way by printing an error number and returning



Nyquist diagram for a second-order servo

to the operating system. An example of this operation is that the program aborts if less than three spot frequencies are entered. There can be little excuse for this bad behaviour from a computer program, particularly one which has reached version 3. The manufacturer is well aware of these deficiencies and is working to improve matters.

Plotting

Graphical output of frequency and time response is available from any node in the system, which might be particularly useful if you are investigating possible saturation effects of amplifiers or devices inside a complex series of feedback loops. Built-in drivers enable the plots to be presented on an Epson-compatible printer, HP plotter or HP-compatible laser printer. Both time and frequency graphs can be expanded using a zoom facility to show specific items in more detail. It is only possible to show one graph on the screen at a time (an exception is a Bode magnitude/phase plot), so performance comparisons at the various nodes of the system must be done with the plotted results.

Manual

Although produced on a low budget, the manual is well written and very comprehensive. It not only covers the operation of the program, but also provides an introduction to control engineering as well as some worked examples, which start with simple concepts such as lead-lag compensation and PID (proportional integral derivative) control. Other topics are non-linear systems and state feedback.

In simulating complex, non-linear, real-world systems, many of the niceties of linear analysis are lost and the only way to ascertain the performance of the system is by simulation. However, this alone is not enough in that it does not determine the sensitivity of the system to the various gains, phase shifts and non-linear attributes. Another related aspect of some non-linear feedback systems is a mode of operation called jump resonance, where the frequency response depends on the direction of the input sweep and the input amplitude. Maxsim only offers increasing frequencies.

Conclusions

Maxsim has the feel of a rather amateur product with a number of rough edges. Its main abilities are in frequency response analysis and to some extent the time domain, the reasons for its low level of interest in the time domain being "historical", according to the maker. Its slow performance and limited features make it seem poor value for money.

Its redeeming feature is that it can tackle very complex multi-loop systems which competing products cannot handle. The system descriptor file uses a simple format which, in principle, could even be generated from a circuit netlist. Used in this way, Maxsim starts to look like a circuit simulation package such as Spice, but its limited library of electronic components and inability to handle time domain response for discrete components limits its usefulness for the electronics engineer. Its real forte is highly complex multi-loop non-linear systems, although with systems of this complexity beware the onset of mathematical problems such as chaos and the deviation of real and simulated performance due to finite number length representation.

The cost of £425 is rather steep for a product with this limited specification, but then there are not many multi-loop simulators to choose from!

SUPPLIER

Maxsim System Simulation for the PC costs £425 excluding vat for a single copy.

Adrian Morris Engineering Ltd, 60 Southway, Totteridge, London

EXAMPLE

As an example, an 8th-order low-pass Chebychev filter with a 2dB ripple in the pass band. It is made up of four 2nd-order sections, each as below. The transfer function for the first block is P1. For the first block, $G = 1/(0.565 + 0.266s + s^2)$. This polynomial fraction is represented in Maxsim simply as a phase shifter block:

P1 1,2, 1,0,0, 0.0565, 0.266, 1

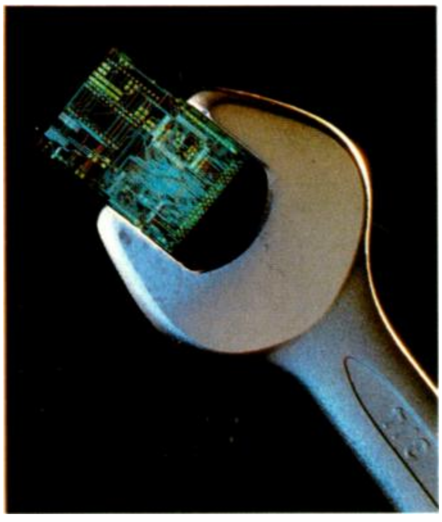
The interpretation of this syntax is: nodes 1 and 2, numerator coefficients for s^0, s^1 and s^2 orders, and three further coefficients for the second-order polynomial in s in the denominator. The remaining three blocks are defined in a similar manner, ending in a normalising gain block. Bandwidth is 1rad/s.

Combining this with the further blocks shown below gives the complete 8th-order filter.

P2	2,3,	1,0,0,	0.3271,0.225,1
P3	3,4,	1,0,0,	0.7098,0.150,1
P4	4,5,	1,0,0,	0.9804,0.052,1
K1	5,6,	0.01286	

Since the blocks are general system blocks, simulation can be performed in the time as well as the frequency domain. Not surprisingly, the time response of this system for a step input shows a considerable overshoot.

Editorial survey: use the information card to evaluate this article. Item G

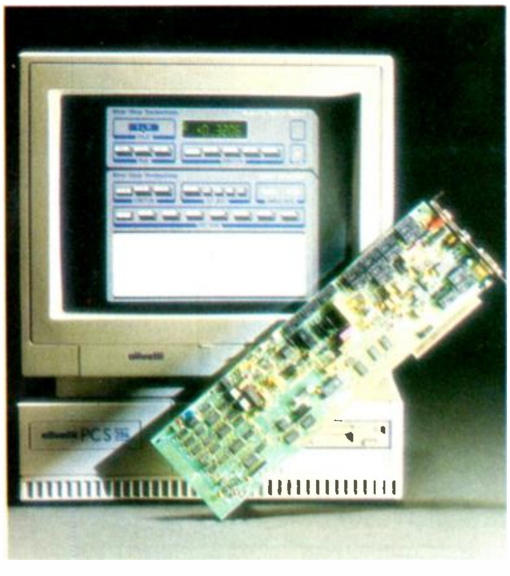


Voltage and current on screen

Blue Chip Technology's intelligent DMM is one of the new breed of virtual instruments for the PC, offering voltage and current measurement, chart recording and data logging. Mike Tooley has been using it for some time and presents his comments

***Extremely useful:** Blue Chip's DMM board provides the major functions of a multimeter with the data logging facilities of a data acquisition system.*

***Good psychology:** most people assimilate analogue readouts faster than the digital equivalaent. This virtual instrument provides both.*



A virtual instrument is simply the emulation of a conventional piece of test equipment based on a microcomputer system fitted with an appropriate expansion card which, in turn, is driven by suitable software. Such combinations offer an increasingly cost-effective solution to the use of traditional stand-alone items of test gear.

At first sight, the concept of a virtual instrument display may appear to be something of a gimmick. Attempting to emulate the front panel of a conventional item of test equipment on the two-dimensional screen of a PC is, after all, something of an artificial exercise when one realises that none of the usual manually operated controls is available! Of course, mouse control adds another (if at times cumbersome!) dimension to this and at least it provides the user with a means of pointing to, and clicking on, the required function.

Behind this is the reasoning that an engineer is much more at home with something that he recognises as part of the usual range of workbench test equipment. Tell him that you will exchange a PC for such stalwart items as a DVM, oscilloscope or chart recorder and you are likely to be given a pretty dusty answer!

The justification, of course, is that virtual instruments provide a tremendous degree of added functionality: not only will they give conventional readings of everyday parameters such as voltage, current and resistance, but will store these values for later analysis and export to software packages such as Lotus 1-2-3. Furthermore, virtual instruments may be readily programmed so that they can form the basis of automatic test equipment systems.

Cost effectiveness

A conventional intelligent digital multimeter such as the Fluke 8840A, or Keithley 197 will set you back between £500 and £750. Add to this basic price an extra £150 to £200 for an IEEE-488 "option" and you have a sizeable outlay. Furthermore, when you purchase such an instrument you pay for a case, a power supply, a front panel fitted with controls and displays, one or more printed circuit boards, the labour to put it all together, overheads incurred with development, marketing and distribution.

Remember, however, that you already have a case, display and power supply already sitting on your bench in the form of your PC. With a virtual instrument product, therefore, the first three items are no longer required; in other words, a greater proportion of your cash can be directed towards the functionality of the instrument in question.

Blue Chip Technology DMM-VIP

This recently introduced intelligent digital multimeter (DMM-VIP) represents the "state-of-the-art" in virtual-instrument products. DMM-VIP hardware consists of a full-sized 8-bit bus PC expansion card, which employs a mixture of surface-mounted and standard technology. The card is fitted with two standard 4mm banana sockets (for signal input) on the industry-standard 0.75in pitch, together with a male 9-way D-type connector for control of an optional external scanner. Board layout is uncluttered and, in many cases, users will not need to change the settings of the configuration jumpers fitted.

Chart recording and data logging

One of the outstanding advantages of the DMM is that it incorporates a chart recorder display, which closely emulates a conventional chart recorder, with moving "chart" and "pen". Chart speed (sampling rate) is adjustable to a maximum of 25 samples per second.

The data logging function, which is available when the chart recorder display is selected, allows the user to log the acquired data in a named disk file, data being stored in standard comma-delimited format which is compatible with most software packages such as Lotus 1-2-3 and Wordstar. On completion of measurements, data may be replayed by the chart recorder display, analysed by other packages (a spreadsheet, for example) or dumped to a line printer in chart-recorder format.

If single-channel operation is not acceptable, an external scanning unit is available to increase the capacity of the basic DMM, chart recorder and data logger to a maximum of 32 channels per instrument. Each channel of the DMM can be set up for a different function and range.

Specification

DMM-VIP offers an impressive specification, which compares favourably with all but the more expensive of conventional bench instruments. It measures direct and alternating voltage (each in four ranges from 200mV full-scale to 300V full-scale), direct and alternating current (each in three ranges from 20mA full-scale to 2A full-scale), resistance (in seven ranges from 20Ω), capacitance (in four ranges from 2nF to 2μF in four ranges) and dBm. Accuracy of the direct-voltage ranges is between ± 0.02% and ± 0.09% of reading, while in AC ranges it lies between ±0.5% and ±1% of reading. AC ranges provide true-RMS indications and the input is rated at 400VDC/400V peak AC maximum.

Accuracy on the resistance ranges varies from ±0.06% on the three lowest ranges to 1% on the 20MΩ range. On capacitance, accuracy is ±2% to ±5%. Instrument display provides 4.5 digits and count headroom before overrange indication is generated amounts to 29,000 counts.

Base address of the instrument is selectable within the PC I/O map between 20hex and 3E0hex — a total of six addresses within the I/O map is required. The instrument may be configured to interrupt levels of between IRQ2 and IRQ7.

SUPPLIER

DMM-VIP is available from Blue Chip Technology, Hawarden Industrial Park, Manor Lane, Deeside, Clwyd CH5 3PP. Phone 0244 520222; fax 0244 531043; Telex 61471.

The package costs £495 (excluding vat) and the optional sequential scanner costs £149 for each group of eight channels (subject to a maximum of £32).

Documentation

The DMM-VIP is provided with a 78-page, A5-format, spiral-bound handbook, which describes installation and application of the chart recorder and DMM, seven appendices providing reference data on clocks and timing, I/O addresses, interrupt levels and calibration. It is laid out in a logical manner and will be of value to the newcomer to virtual instruments as well as providing more specific details on measuring techniques. Sections are included for "experienced users" and the handbook also includes a "Quick-Start Guide" for people who may be in a hurry to get the system up and running.

Installation and programming

The board is factory configured to an I/O base address of 0300hex, interrupt request level 3 and internal clock. Default values in the setup software match these settings; all that is required of the user is to press the RETURN key in response to the setup questions. Fitting the board and installing the software is therefore simplicity itself and, provided the few basic instructions are followed, the user should be presented with a fully functional front-panel display in minutes.

CPERATING ENVIRONMENT

DMM-VIP requires an IBM-PC/XT/AT/386 (or compatible) with one 8-bit bus slot free and a standard mouse. A minimum of 640K of ram is needed, together with EGA or VGA graphics (either colour or monochrome).

Programming the DMM-VIP is very easy, thanks to the driver software provided with the package. The technician or engineer with only a modicum of software knowledge will be able to control the instrument from packages such as Microsoft QuickBASIC or C.

Operation

DMM-VIP has been in regular use in my workshop over the last two months, installed in a DSC Turbo AT-compatible fitted with 1Mbyte ram, Microsoft bus mouse and EGA colour display. During that time, I have used the unit in a variety of tasks, ranging from the purely mundane to the abstruse. I was able successfully to "automate" a number of measurements of RF transistor parameters (with data logged and exported to a popular public-domain spreadsheet). I also found the chart-recorder facility useful when observing the temperature rise within a complex heat-sink used with a prototype power amplifier — a task which would otherwise have required the manual plotting of a graph.

For many of the mundane measurements, however, I must admit to being tempted (at least initially) to return to my bench DMM, even though the mouse/screen interface was found to be somewhat more workable than I was originally prepared to give it credit for.

Conclusion

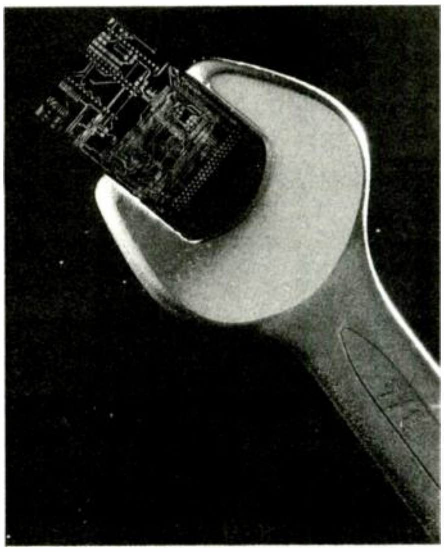
The Blue Chip Technology DMM-VIP offers a full range of DMM specifications in a package which cannot be faulted for versatility. It must surely represent outstanding value at less than £500.

Editorial survey: use the information card to evaluate this article. Item H

CIRCLE NO. 114 ON REPLY CARD

CIRCLE NO. 115 ON REPLY CARD

CIRCLE NO. 116 ON REPLY CARD



PCL-860: DVM performance on a PC

How well does the PCL-860 4.5 digit voltmeter PC expansion card measure up? Allen Brown plugs in to find out.

Explosive growth in expansion cards for the PC means that now the electronics engineer can quite easily have a machine dedicated to data acquisition and measurement: drop in the appropriate card and the PC is transformed into a logic analyser, a digital 'scope or a host of other devices.

One such card is the PCL-860 DVM from Fairchild — a full length expansion card providing a facility for measuring voltage and resistance.

Four voltage ranges span 200V (resolution 10mV) to 200mV (resolution 10µV) for both DC and AC inputs with an accuracy of ±0.003%. Resistance is measured by using a four wire arrangement where two of the wires provide a current source.

Minimum resistance range is 20Ω (resolution 1mΩ) and the maximum is a rather limited 20kΩ (resolution 1Ω).

As with the majority of expansion cards, the PCL-860 has a switch setting to allow users to choose their own PC I/O address with appropriate wait states to enable the card to be used with high speed PCs. It has a 16-bit A-to-D converter and a bandwidth of 10kHz.

Installation

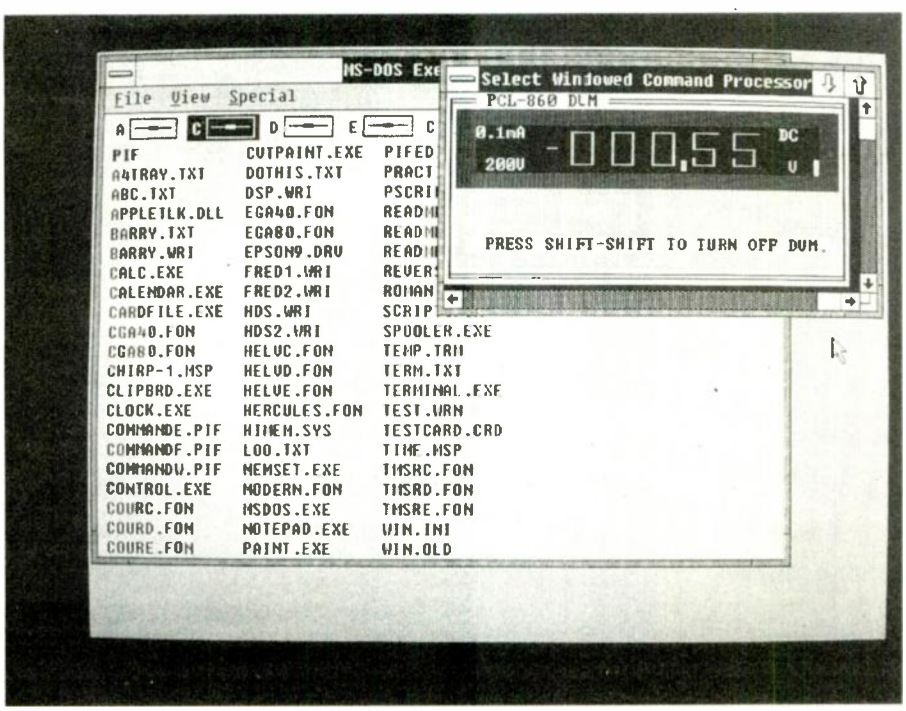
Installation of the card is very straight forward, though it is advisable to insert the banana plugs in the card's bracket sockets first. They are a very tight fit and resulted in the bracket bending when the card was in place.

The PCL-860's own device driver (installed in the PC's CONFIG.SYS file) allows a pop-up display to be evoked by pressing the two shift keys. An attractive display panel (**Fig. 1.**) shows the device settings and four function boxes activated by cursor keys.

Function boxes offer the various option setting on the card, for example ACV or DCV and display rate — display rate is adjusted by accessing the FUNC. box and has a maximum value of 10/s. But in these days of multitasking front ends, the PCL-860 requires a dedicated dos window (COMMAND.EXE) which can take up a lot of memory. An example (shown in Fig. 1.) is where the host multitasking environment is Windows/386.

For British keyboards, the PCL-860 requires a terminate and stay resident (TSR) routine which must be evoked once entry into the command window has been made. But the DVM becomes

Fig. 1. PCL-860 pop-up display within a Windows environment.



once entry into the command window has been made. But the DVM becomes inactive when the window is put into background mode, which is a little disappointing.

Adding to its functionality, the PCL-860 can be driven from a number of high-level languages and Fairchild provides sample programs written in C, Basic and Pascal.

A set of command instructions allows the user to configure the card and control its operation from within a program, and the extensive C sample programs give a good insight into the programming possibilities held out by the PCL-860.

Data can be imported from the card and further processed or stored on disk for future analysis.

A standard set of leads and terminators is provided and the accompanying manual is quite well written with many diagrams to assist understanding operation of the PCL-860 from a programmer's perspective.

Chapter six covers calibration procedures, effected by using a calibration software routine and manually adjusting the board's potentiometers. The method is not particularly appealing since auto-calibration procedures have been around for several years now.

PCL-860 data

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Supplier: Fairchild Ltd, Eastpoint, Burgoyne Road, Southampton SO2 6PB. Tel 042121-6527. £349 plus VAT.

Reservations

My reservations on the PCL-860 focus on four aspects; I must question whether a 16-bit A-to-D converter is adequate for a DVM. I also do not like the way resistance is measured using two wires for a current source. If lead resistance needs to be considered, then four wires are necessary (there is no reference to lead resistance in the manual).

There is no option for measuring current, which is a standard feature on most DVMs. Lastly, at £350 the board is not cheap.

But putting my reservations aside, the product performs well within the specifications laid out in the manual and if a user has a requirement for a PC-based DVM with these specifications, then the PCL-860 is a product worth considering.

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ON THE RIGHT TRACK

Navigating a small boat is no longer a matter of the wet finger held aloft. Technology has made inroads and Steve Rogerson reports on the latest equipment seen at the Boat Show

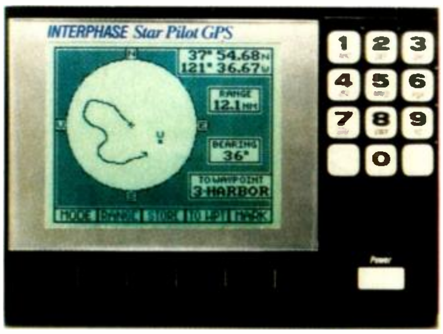
Marine electronics is becoming big business. Small boat owners have never had a better opportunity to pour money into high technology than at this year's Boat Show. The satellite based global positioning system (GPS) is emerging as a clear winner for electronic navigation against the traditional land based systems of Decca and Loran.

The big boost for GPS has been its increased coverage with 18 of the planned 24 satellites in operation. This allows users to take a fix for more than 23 hours in any 24 hour period. By the end of this year, shuttle launches permitting, all the satellites should be up and giving an around-the-clock service.

There has been a dramatic fall in price for GPS systems. Four years ago a unit could easily cost £10,000. As recently as last year the price was in the £2500 bracket. At this year's boat show there were sets available for as little as £1300 with predictions that the price will drop below £1000 by the end of the year. They are still more expensive than the land based equivalents, typically £600 to £700 for a Decca and as low as £500 for Loran, but some pundits were predicting that within five years the price differential will have disappeared completely.

GPS has also been given an increase in popularity in a strange spin-off from the Gulf crisis. When the GPS satellites first went into orbit, the US Government became concerned about the 10 to 15m positioning accuracy achieved by civilian sets. The worry was that it could be integrated into a guided missile system or otherwise used for military purposes.

The US authorities responded by putting a scrambling system on the satellite signals that reduced the accuracy to only 100m; military units were fitted with a descrambler. But with the large deployment of troops into a featureless desert, every unit and section was to be given a GPS receiver. The trouble is that not enough military units could be sent to the area in time and so civilian units were pressed into service. This led to the US Government switching off the scrambler



Navico's Star Pilot GPS costs £2395 and has a 128 X 160 pixel display, which is responsible for the elevated price. Vessel's track is displayed.

system - called SA for selective availability. The US has said SA will go back on after the Gulf crisis is over, but that decision will surely depend on the progress of the Russian Glonas system.

This is again a satellite based system with no SA equivalent planned. Russia is approaching manufacturers with a view to producing versions in the West and at least one US firm is making a hybrid GPS/Glonas unit. If cheap Glonas systems come on the market, then it seems inconceivable that the US would switch SA back on, thus reducing the positioning accuracy for civilian users: doing so would kill sales of the US system hardware stone dead.

Chris Carter from Navstar put it this way: "If a good, commercially viable Glonas receiver is put on the market and the US implements SA, then Glonas would outsell GPS, which would be commercial suicide for the US manufacturers." But Brian Grant, a consultant for Navico, said that Glonas is too sophisticated for the leisure industry. He didn't envisage that low price Glonas sets will come in, at least not as low as GPS.

Satellite systems enjoy virtual global coverage. In contrast, Loran only covers the American coast states, Norway, Iceland, the north of Scotland, the Mediterranean, Saudi Arabia, Japan and part of the South China Sea. Further transmitters are planned for India but it still leaves large areas of the globe uncovered including most of the British Isles.

Decca has all of the British Isles covered, along with most of Scandinavia and the north European coast. There are further systems in Canada, Japan, the Gulf, India, Bangladesh, South Africa and Australia. Land-based systems are also more prone to weather and time-of-day interference and their range and accuracy are not as good though Decca, at 25m, does beat a scrambled GPS. Loran, at 200m, is not a contender.

Political problems also come into play. The Decca system was taken over by the British Government about three years ago

Philips's ap Navigator six-channel stand-alone GPS at £1950, which displays data received from wind instrument systems, with lay lines for true speed over ground.

although Decca still manages it. The problem is that the Government is only guaranteeing transmissions until early 1997, after which Decca may not exist unless a private firm takes over the transmitter chain. The Government intended to back the Loran system, assuming that it would get funding from the European partners.

However, other countries are updating their Decca chains and seem unlikely to sanction extra money for Loran. Navico's Grant summed the commercial possibilities this way: "In five year's time GPS will have very low price systems and be the main player. Loran will be in Europe and be sustained for European military reasons as an alternative to GPS and Glonas.

"But GPS is so universal and accurate that it will be in the hands of the US with no commercial back-up if European countries do not put up the money. It will be a problem getting fishermen to scrap Decca, but GPS is so accurate that some fishermen are already asking for it."

DIFFERENTIAL GPS

GPS systems can be made more accurate using a technique called differential GPS. For this to work a second GPS receiver is needed at a known fixed position. The mobile GPS takes readings from the fixed station as well as the satellites to improve the fix. With GPS descrambling, it is possible to get accuracies within a few centimetres, ideal for surveying applications. Even with the SA switched on, accuracy can be within 20m at a limited range. The 20m accuracy can only be achieved within 30km of the fixed base station, and reduces to 100m at 160km. Some manufacturers are thinking of setting up their own base station networks for differential GPS if the US turns SA back on.

NEW GPS RECEIVERS

Companies showing new navigation products all went for the GPS system with price as the selling point. The winner at £1300 wasthe Pronav GPS100 available from three UK distributors - Regis Electronics, SM International and Marine Electronics Services. It measures just 159 x 100 x 51mm and weighs about 0.7kg. But the firm must have been looking at last year's price lists when it made its claim that it costs around £600 less than its nearest rivals.Try telling that to Marconi which had a range of Koden GPS units priced between £1350 and £1900 including the GP910. Like the Pronov product, it has an accuracy of 15m. And Shipmate was showing its RS5500 unit at less than £1500 with an accuracy of 8m. Not really in the price war at £2395 was Navico with its Star Pilot GPS receiver, but most of the extra cost clearly went into its large 128 x 160 pixel supertwist lcd display Accuracy is15m.Cetrek was doing something different. A GPS system is made up of a black box, antenna and display, but the firm was selling its black box for £1295 for owners of its chart based navigator. This is a cartridge system with each cartridge containing details of a particular area of coastline. The GPS system links into It to show sailors where they are on the display. The chart system itself costs £3000.Even more different was the Navstar XR4-PC.This is a computer expansion card intended for the OEM market and people who want to value add to systems. It turns an IBM XT or AT-compatible computer into a GPS development system.

Editorial survey: use the information card to evaluate this article. Item J

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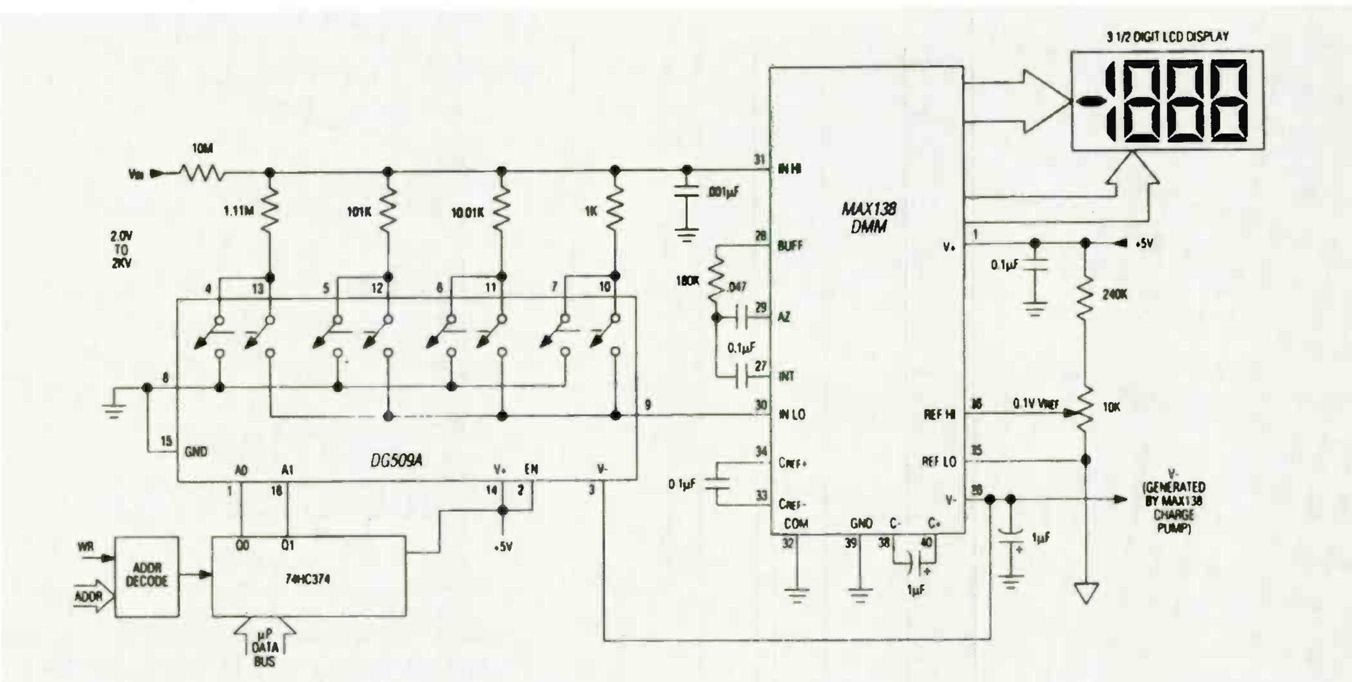
Adding a range switch to a DPM



Although many low-cost digital panel meter chips now exist, they are commonly designed for a single range and have no provision for different voltage ranges. When input switching is needed, one solution is to use solid-state devices in a divider arrangement, but this does mean that the switch resistance has to be taken into account when designing the divider. Since the resistance is not accurately known and varies with temperature and power supply voltage, the method is not ideal.

In the circuit shown, which is taken from the Maxim 1990 Applications Handbook, using the differential inputs of the MAX138 panel meter module removes the IR voltage drops across the analogue switches in series with the precision resistors. The second set of analogue switches has no current flowing in it and simply connects the 138 input low pin to the bottom of the divider resistor in use, so that the voltage drop in the current-carrying switch is not seen.

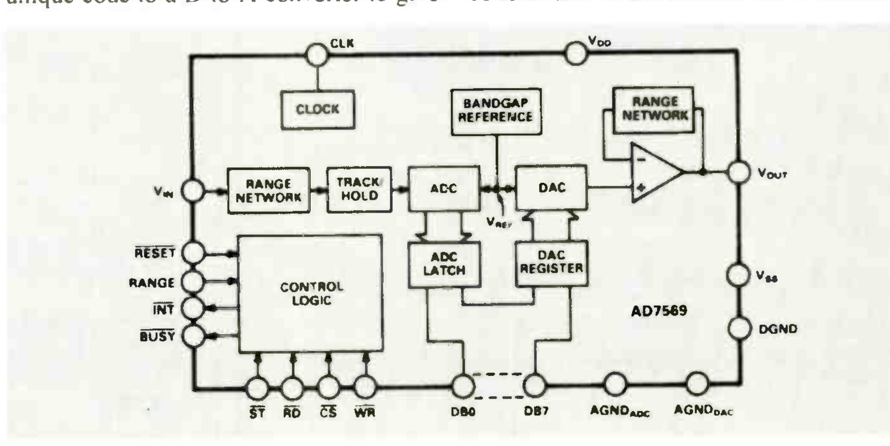
A negative supply voltage is needed by the analogue switch if it is required to pass positive and negative inputs. Since the 138 contains a charge pump to generate negative voltages, low-current switches such as the DG509A shown can use this supply, available at the 138's V- pin, at currents up to 0.5mA.

Maxim Integrated Products (UK) Ltd, 21C Horseshoe Park, Pangbourne, Reading RG8 7JW.

Function generator with linearisation

When a complex or discontinuous function must be generated, it is now common to use an A-to-D converter feeding digital addresses to a rom, which provides a unique code to a D-to-A converter to give an analogue output. Any function is obtainable with the correct rom programming.

Analog Devices's AD7569 (below) contains both data converters, so that with this device, a Sierra Semiconductor SC22102 rom and a quad Nand such as the 4093 to carry out logic and timing functions, a three-chip function generator can be made, as described in Application Note E1369 and shown in **Fig. 1**. Input and output ranges are pin-programmable. Since input impedance is low and bias current rather high, it is expected that an input buffer will be used. Data from the A-to-D and to the D-to-A use a common



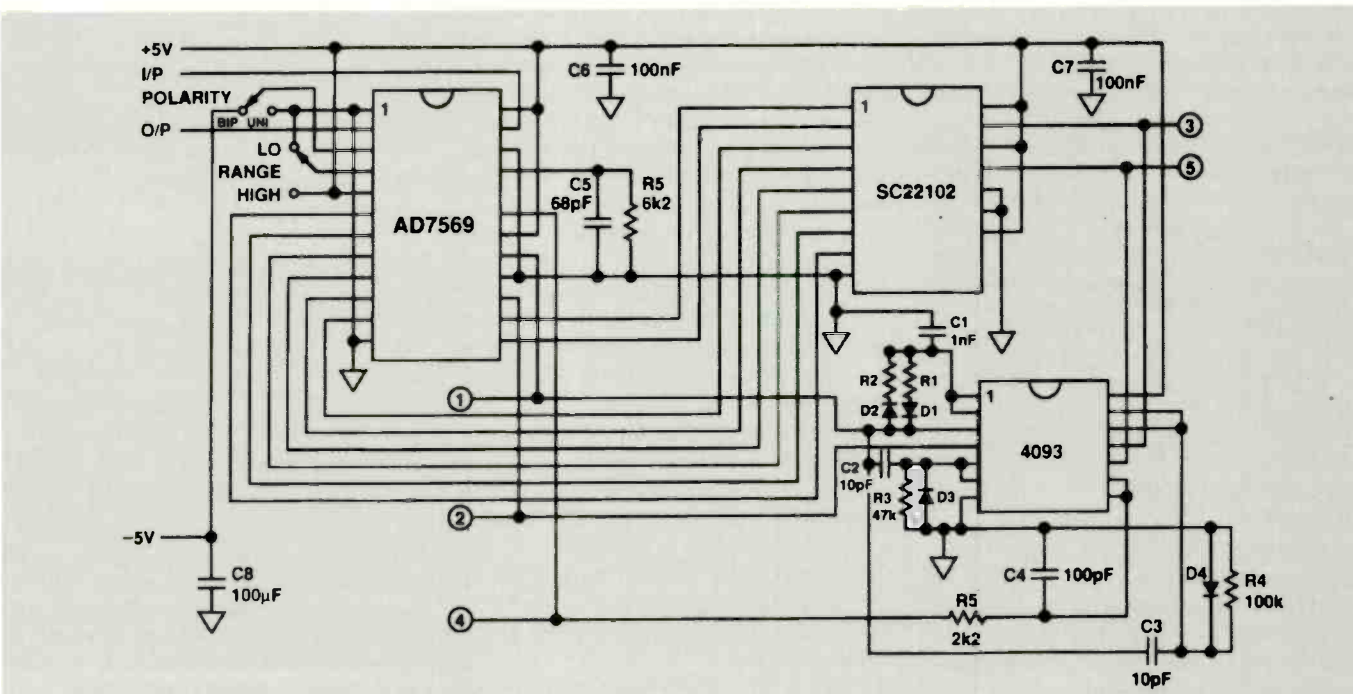
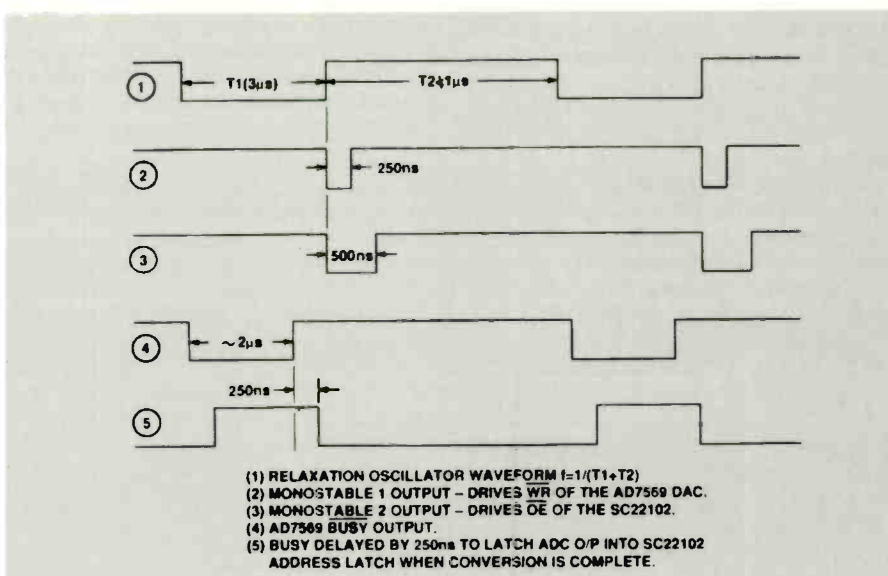
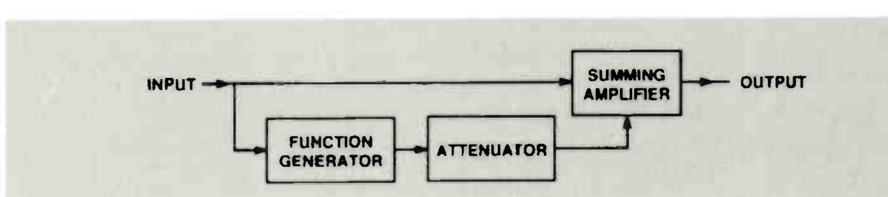


Fig.1. Three-chip function generator.

Fig.2. Waveforms in the function generator. Circled numbers refer to Fig.1.

Fig.3. Using the generator to linearise signals from a transducer.





port and it is therefore convenient to use a rom with multiplexed address/data bus, the SC22102 eeprom being such a device. Both converters are 8-bit devices, so accuracy is 0.4%.

Clock pulses at a maximum frequency of 250kHz, A-to-D triggering and write/read control is provided by the four gates in the 4093. Waveforms, identified by circled numbers, are shown in **Fig. 2**.

No setting up is needed unless the sampling frequency is to be precise, in which case R_1 should be set so that T_1 is at least 500ns longer than the BUSY signal of the AD7569 and T_2 then set to give the correct frequency.

Programming the rom is simple and the author points out that he built a programmer to plug into he Centronics port of a personal computer (a 12 year old PET with a modified operating system).

One application is that of the linearisation of transducer signals: **Figure 3** shows the principle. If the non-linearity of the signal is 2% and the correction applied to the signal from the function generator's A-to-D is 2%, then the resolution to which correction is applied is the 0.4% of the function generator multiplied by 2%, which is 0.008% or around 14 bits. The application note gives full details.

Analog Devices Ltd, Station Avenue, Walton on Thames, Surrey KT12 1PF

Turning off mosfets

A mosfet's input capacitance amounts to several thousand picofarads, which must be charged to 5 or 10 volts to turn the mosfet on and discharged to turn it off. Turn-on is relatively simple, but to drive the input voltage below the gate/source threshold voltage needs some kind of active network, which normally consists of several discrete devices, as seen in **Fig. 1**. Motorola's Engineering Bulletin EB142 describes an integrated device to perform the function rather better and at lower cost.

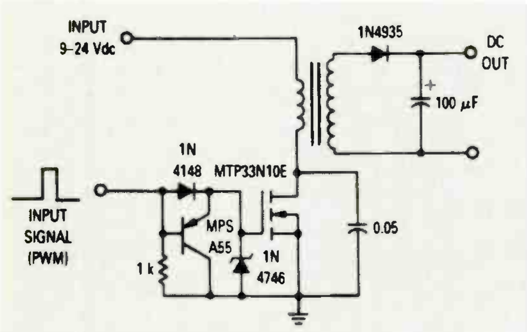


Fig.1. Common mosfet drive arrangement.

In the circuit of Fig.1, the gate capacitance is charged to the level of the input less the diode drop, the base of the MPSA55 being clamped off by the diode. When the input goes low, the transistor turns on to discharge the mosfet input capacitance rapidly. The zener protects the gate from overvoltage.

Motorola's MDC1000A/B/C (Fig.2) is an integrated equivalent to that in Fig.1, except that the p-n-p transistor is replaced by a complementary pair to form a silicon controlled rectifier, which discharges the mosfet gate capacitance faster; the protection zener is also incorporated. A circuit symbol for the device is shown in **Fig.3**. When the input goes low, the SCR turns on rapidly, the gate capacitance being discharged until the SCR turns off at the point where the mosfet gate charge is too low to provide holding current for the mosfet. Mosfet gate voltage at this point is less than 1V and the time to discharge 1000pF from 9V to 1V is 15ns.

Figure 4 shows the MDC1000A used in the PWM switch of a power converter, in which current is taken from the emitter of an output transistor in the MC34060A oscillator and passed to the mosfet via the MDC1000A. The 300ohm resistor limits current to the turn-off device and the 680pF capacitor provides a little extra urgency at turn on.

Motorola Ltd, European Literature Centre, 88 Tanners drive, Blakelands, Milton Keynes MK14 5BP.

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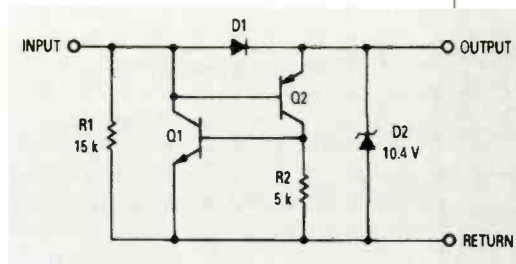


Fig.2. Integrated drive using complementary pair.

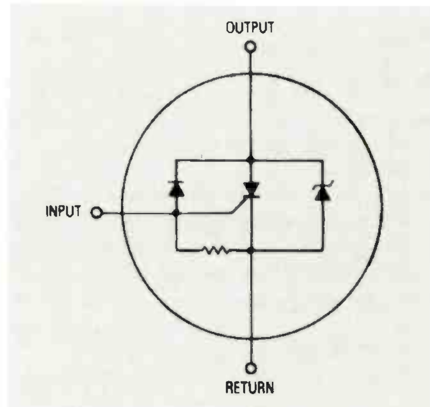
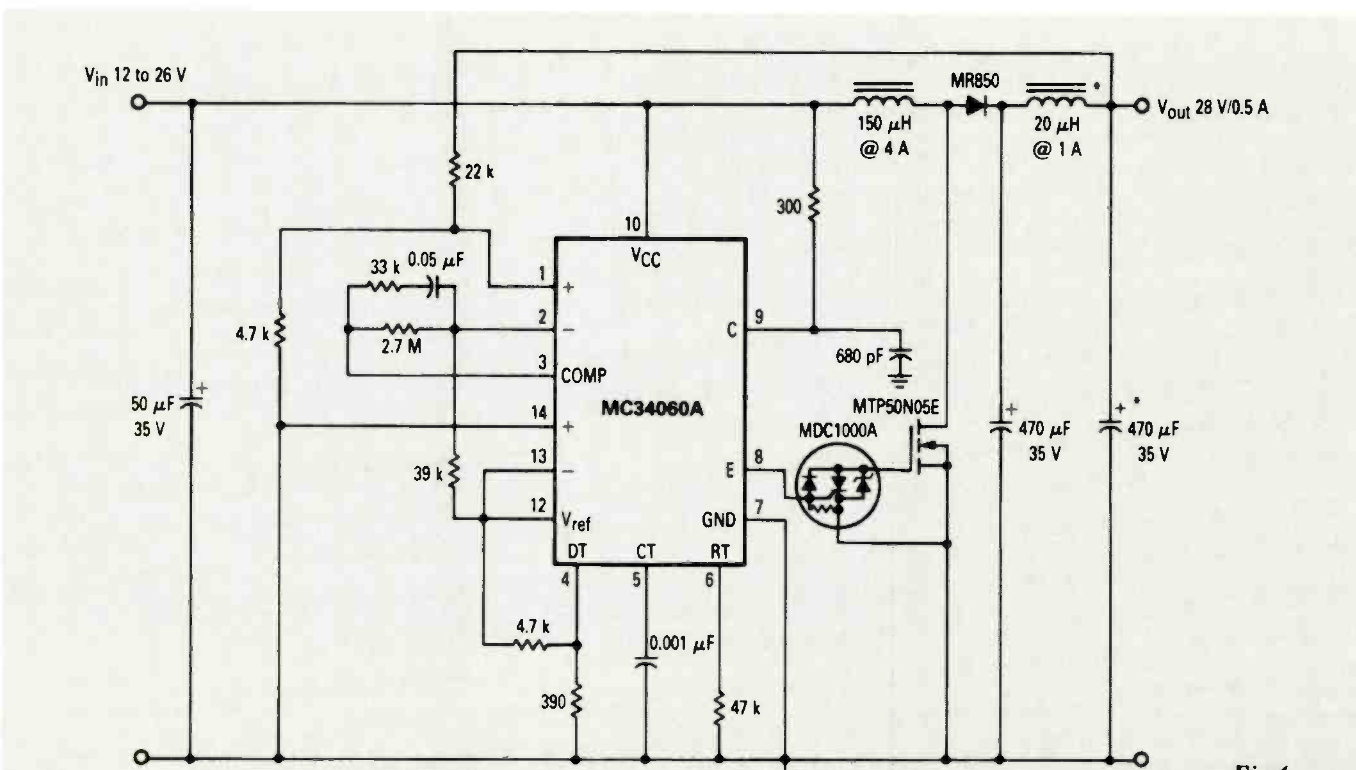


Fig.3. Circuit symbolfor MDC1000.

Fig.4 below. MDC1000 used in PWM switch of power converter.



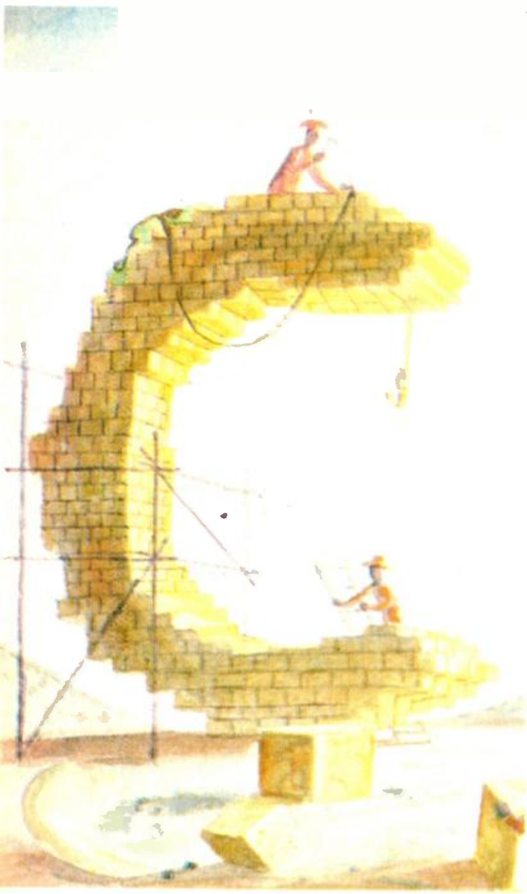
*Optional to minimize output ripple

Fig.4

CIRCLE NO. 124 ON REPLY CARD

CIRCLE NO. 123 ON REPLY CARD

CIRCLE NO. 125 ON REPLY CARD



INTERFACING WITH C

PART 13

Kalman filters are not exclusively the preserve of mathematicians. In this part of his series on C, Howard Hutchings brings the subject down to earth by describing a practical filter used for measuring temperature in the presence of noise.

If you are not confused, then you are misinformed

Kalman filters — predicting uncertainty

Kalman filtering is an important computer application and a specialist area. Connecting a PC to an external device is an effective means of acquiring a realistic understanding of this method of digital-signal processing. The aim is to remove random fluctuations and to establish trends. In this sense, the Kalman filter is a digital estimator designed to remove noise, although this is not clear from the literature. Most books are written by specialists who seem to think Kalman filters exist for the purpose of manipulating mathematical equations. This makes getting started very difficult. I think in terms of specifics rather than generalisations. Show me a problem, signpost a solution, and let me demonstrate that it works. In this way, I feel comfortable and I am happy to take more ambitious abstractions on board.

Your comprehension of the subject may fall under one of the following profiles:

(1) You already use Kalman filters successfully and the terms digital filter, state variable, mathematical model, autocorrelation, variance, mean-square error, and random noise are well understood.

(2) You have heard of Kalman filters, but never found the time to fully understand them.

(3) You have never heard of them, but the prospect of predicting order out of apparent chaos has a certain perverse appeal.

Numerous military, industrial, and scientific applications exist. Undoubtedly, many of the remarkable technological achievements of the past 30 years are due in part to Kalman filter theory. A few of the more spectacular include:

— the navigation of the Apollo spacecraft — this involves mid-course correction culminating in the control of the lunar lander;

— the guidance and control of Exocet missiles which are skimming a few feet above the waves in the presence of noisy sea swell;

— satellite navigation as an aid to precise ship docking and manoeuvre;

— and tracking radars and the control of auto-pilots.

Despite the complexity of the engineering system, the fundamental problem remains of how to recover the characteristics of a deterministic signal corrupted by stochastic noise. Here deterministic means exact or predictable, whereas stochastic describes a process made up of random events. These appear unpredictable to an observer, but can be characterized by statistical methods. I will describe my experiences when interfacing an Analog Devices temperature transducer AD590 to a digital computer IBM PC clone, through a 12-bit a-to-d converter. The signal was deliberately corrupted by random noise before being processed in real-time through a Kalman filter written in C. Finally, the processed output was displayed graphically through an EGA card and colour monitor.

By way of a comparison, the processed output will be shown with no filtering at all, as well as the effects of a 5-term moving averager. Remember this is reality, not a game played on a blackboard where everything works perfectly first time. Be prepared to get it wrong before you get it right and learn to try a little harder next time. By deliberately selecting a relatively modest system to control and monitor, it will be possible to see what is going on without being overwhelmed by detail and complexity.

To help you to participate fully in the discussion, it is first necessary to introduce a few terms from elementary statistics. **Fig. 8.1** represents a continuous random-signal voltage which may take any value in the range ±5V, for example.

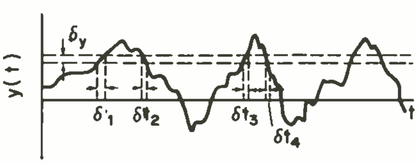


Fig. 8.1. Quantifying random signals using the probability density function.

To learn a little more about the characteristics of this signal, it makes good sense to ask for what fraction of the total observation time T_o does the signal occupy a particular voltage range? For example, the tram-lines drawn in Fig. 8.1 indicate the time spent in the range δy and they enable us to compute the sum:

$$q = \lim_{T_0 \to \infty} \frac{(\delta t_1 + \delta t_2 + \delta t_3 + \delta t_4 + \ \ldots)}{T_0}$$

Examination of this expression will soon make evident that q tends to zero as the observation time T_o becomes infinite. However, the division of q by δy as the interval between voltage ranges shrinks to zero does tend to a definite limit. This is sufficiently important to be given a special name — the probability-density function symbolized by $\rho(y)$. Much of the subsequent work will rely on some comprehension of the terms mean value, variance, and mean-squared value as a way of describing the characteristics of a random signal. It is appropriate to advertise the first and second moments of an amplitude distribution for both continuous and sampled data signals, as in the box below. A few words on notation will also be relevant. It is customary to identify the operation of evaluating the mean or expected value of a data set by E. Thus, the mean or expected value y is given by $E[y]$.

Characterizing stochastic noise — Noddies' guide to statistics

Most of us have a good idea of what is meant by the average value, but the concept of stationarity may not be quite as clear. For example, the mean or expected value is the usual arithmetic average summed over all the samples, then divided by the number of samples. How would the mean value be affected if the sample number were increased? If the statistical properties remain unchanged, then the signal would be characterized as stationary stochastic. This could be of considerable significance to any prospective population planner anxious to predict future trends. How far back in time should he go to be confident of his figures? In signal-processing terms, this problem has already been addressed using a 2-term moving averager. Instead of processing all the terms, the average is computed using a moving mean. Because of the small number of samples, expect considerable variation in the calculated mean. Clearly, the variation between samples is an important parameter in random-signal analysis. This is quantified by statisticians as the variance.

To compute the variance, first subtract the mean value from the signal, then square the result and evaluate the average. With knowledge of the variance σ^2 and the mean value y, the mean square value

$\overline{y^2}$ can be predicted using $\overline{y^2} = \sigma^2 + (\bar{y})^2$. It is interesting that electrical engineers have been using this result for years to compute the total average power of complex waveforms. Consider how to evaluate the total average power of a signal made up of a DC component, together with an AC (or time-varying) component, developed across a 1Ω resistor. Obviously, the square of the mean value is the power

Statistics of a random variable

Continuous signals

Obtaining the mean value from the amplitude distribution.

First moment of y

$$\bar{y} = \int_b^a y\,\rho(y)\,dy$$

Evaluating the mean-squared value.

Second moment of y

$$\overline{y^2} = \int_b^a y^2\rho(y)\,dy$$

Discrete signals

Average value of signal

$$\bar{y} = \sum_{m=1}^{n} \rho_m y_m$$

Mean-square value

$$\overline{y^2} = \sum_{m=1}^{n} \rho_m y_m^2$$

Standard deviation σ is related to the variance by

$$\sigma^2 = \sum_{m=1}^{n} (y_m - \bar{y})^2 \rho_m$$

Electrical analogy

$$\overline{y^2} = \sigma^2 + (\bar{y})^2$$

where $\overline{y^2}$ is total average power and σ^2 is average AC power.

Alternative notation

$$E[y^2] = \sigma^2 + E[y]^2$$

If the DC component is zero, the variance is equal to the mean-square value.

in the DC component, whilst the variance represents the AC power. Examine the relationship closely. Observe that, when the mean value is zero, the square root of the variance (defined as the standard deviation) is equal to the root mean-squared value (r.m.s) of the waveform. The noise generators shown in **Figs. 8.7** and **8.8** are designed to produce a random-noise voltage with a bell-shaped distribution curve. The theoretical Gaussian curve of a random signal with mean value $\bar{y}$ is shown pictorially in **Fig. 8.2**. There are some interesting and important points to note about the idealised mathematical model, which characterizes random behaviour in terms of the parameters $\bar{y}$ and σ. Use the normal distribution curve to apply scientific method to predict the likely behaviour of apparently unrelated events.

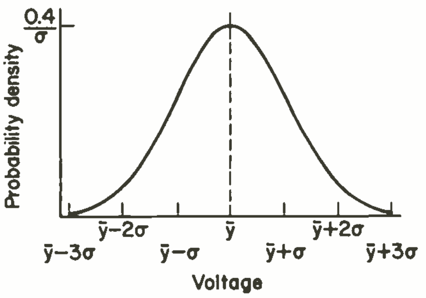


Fig. 8.2. Theoretical Gaussian curve for random signals normalised in terms of mean and standard deviation.

(1) The curve is symmetrical about the mean.
(2) The probability of a voltage lying between two given values is simply the area under the curve between the appropriate limits (**Fig. 8.3**). For example, the area between the mean value $\bar{y}$ and $(\bar{y} + \sigma)$ is obtained from **Table 1**. So it can be concluded that the probability of the signal lying between the mean and one standard deviation above the mean is 0.341. Because the curve is symmetrical, it follows that the probability of the noisy signal having a value within one standard deviation each side of the mean will be 0.682.
(3) The Gaussian curve is almost zero beyond $(\bar{y} + 3\sigma)$. In other words, the probability of the signal being more than plus or minus three standard deviations away from the mean is very small.

A simple example will help you make the necessary connections. A noisy instrumentation signal is sampled by a 3-bit a-to-d converter. Analysis of a large number of samples gives the 8-level amplitude distribution shown in **Fig. 8.4**.

(1) Evaluate the mean or expected value $E[y]$.
(2) Calculate the mean-square value $E[y^2]$.

Area under Gaussian curve

y	Area $\bar{y}$ to $\bar{y}$+y (3 sgt figs)
0	0
0.5σ	0.192
σ	0.341
1.5σ	0.433
1.645σ	0.450
1.96σ	0.475
2σ	0.477
2.5σ	0.494
2.575σ	0.495
3σ	0.499

Table 1

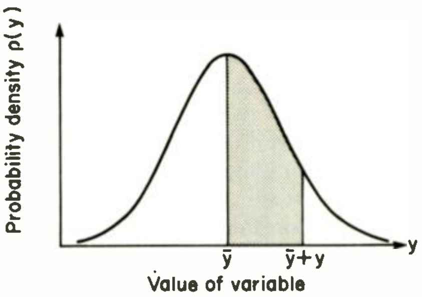


Fig. 8.3. Shaded area is related to numerical values of Table 1.

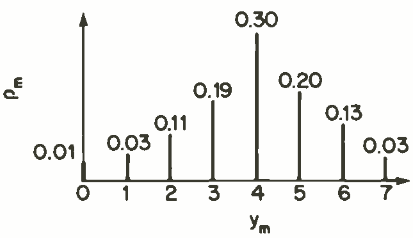


Fig. 8.4. Eight-level amplitude distribution.

(3) Determine the standard deviation σ.
(4) Confirm the total average power is the sum of the variance (average AC power) and the power in the DC component.

The average value is given by:

$$E[y] = \sum_{m=1}^{n} \rho_m y_m$$

$$=0{\cdot}01\times0+0.03\times1+0.11\times2+0.19\times3$$

$$+0.30\times4+0.20\times5+0.13\times6+0.03\times7$$

$$=4.01$$

The mean-square value is obtained by evaluating the second moment of the amplitude distribution, using:

$$E[y^2] = \sum_{m=1}^{n} \rho_m y_m{}^2$$

$$=0.01(0)^2+0.03(1)^2+0.11(2)^2+0.19(3)^2$$

$$+0.30(4)^2+0.20(5)^2+0.13(6)^2+0.03(7)^2$$

$$=18.13$$

The standard deviation is a measure of the overall spread of the signal about the mean. It is defined as the square root of the variance.

$$\sigma^2 = \sum_{m=1}^{n} (y_m-\bar{y})^2\rho_m$$

$$=(0-4.01)^2\times0.01+(1\text{–}4.01)^2\times0.03$$

$$+(2\text{–}4.01)^2\times0.11$$

$$+(3\text{–}4.01)^2\times0.19+(4-4.01)^2\times0.30$$

$$+(5-4.01)^2\times0.20$$

$$+(6-4.01)^2\times0.13+(7-4.01)^2\times0.03$$

$$=2.05$$

Hence, the standard deviation is given by $\sqrt{2.05} = 1.43$

The aim is to verify that the mean-square value (total average power) is the sum of variance (average AC power) and the square of the mean (power in the DC component).

$$E[y^2] = \sigma^2+(E[y])^2$$

$18.13 = 2.05 + (4.01)^2$ which confirms the anticipated result.

Tracking a time-varying signal in the presence of noise — optimal estimation

Before the characteristics of an optimum recursive estimator or a scalar Kalman filter can be established, it is necessary to quantify the measurement criterion upon which the best possible estimate of the noisy variable is made. This problem was investigated almost two hundred years ago by Karl Frederick Gauss in connection with the prediction of planetary orbits, based on noisy or uncertain observations. Gauss adopted the method of least squares to find the best approximation to a function from a range of experimental data.

Real-time estimation based on a

minimised mean-squared error criterion remained intractable until about 1960, when R. E. Kalman, and others, demonstrated how the algorithm might be implemented recursively. Consider the elementary recursive algorithm:

$$y(n) = ay(n-1) + bx(n)$$

Here a and b are constants subject to the constraint $a + b < 1$ to ensure the filter remains stable and well-behaved. A weighted version of the current input $x(n)$ is being added to a weighted version of the previous output $y(n - 1)$. Provided the values of a and b are chosen carefully, any abrupt or sudden changes in the input will be smoothed out. This will leave only the long-term trend. Anyone familiar with digital filters will have recognised this as a simple first-order low-pass filter, whose output will "track" or follow a slowly changing input signal whilst ignoring the high-frequency noise, as in **Fig. 8.5**.

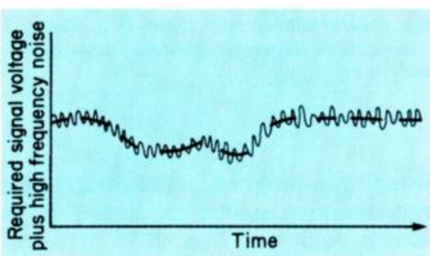


Fig. 8.5. Elementary first-order low-pass digital filter removes HF noise, allowing output to follow slowly changing input signal.

This is a useful starting point towards understanding the mechanism of a Kalman filter. However, a couple of small but important modifications need to be introduced. Instead of a and b being constants, allow both to be functions of n. So, the recursive algorithm may be written as:

$$\hat{y}(n) = a(n)\,\hat{y}(n-1) + b(n)x(n)$$

You may have noticed the subtle change in notation. The "cap" or "hat" over the y terms are intended to represent an estimation. In other words, the current predicted output is made up of two weighted terms — the previous estimate and the current noisy measurement. The relative weighting of each will depend on the confidence the filter places in its own prediction, or in the observation. The next step is to establish the best estimate $y(n)$, in the sense of the minimised mean-square error,

$$E[(\hat{y}(n) - y(n))^2]$$

In doing so, the relationship between $a(n)$ and $b(n)$ will be established, and the need to incorporate a model of the signal into the Kalman filter will be demonstrated. The mathematical details are contained in Appendix 1.

Applied optimal control

To design a Kalman filter, it is necessary to know the characteristics of the signal and the anticipated values of signal and measurement noise. A convincing practical example, which requires a relatively modest mathematical toolkit, is the measurement of temperature using the Analog Devices AD590. This 2-terminal integrated circuit transducer produces an output current proportional to absolute temperature (1μA/°K) in the range −55°C to +150°C. An attractive feature of the data sheet is the thermal circuit model and the time constants for both the F (metal case) and H (ceramic) packages (**Fig. 8.14**). The comprehensive data sheet also provides a variety of applications circuits. Here, the 2-trim circuit was selected which gave an output of 100mV/°C over the range 0°C–100°C. The differential equation which models the dynamic characteristics of this transducer is given in Appendix 2, along with the model showing transformation from continuous to sampled data.

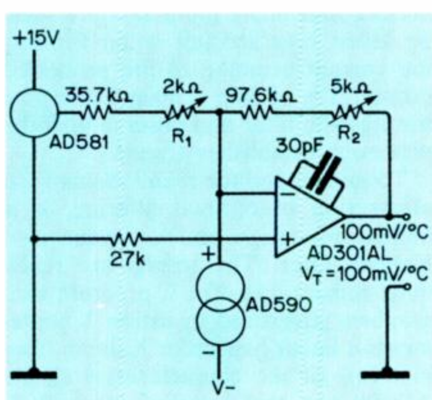
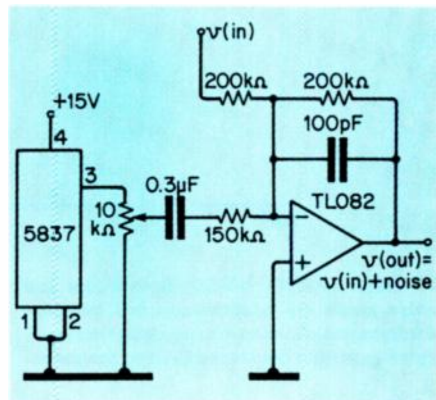


Fig. 8.6. Measurement of temperature using the AD590.

To complete the hardware description, combine the output of the transducer with the random-noise generator shown in **Fig. 8.7**, then process through the 12-bit a-to-d AD574A contained on the Blue Chip analogue input card AIP-24, which is conditioned in the range 0–10V. Adapt the circuit shown in **Fig. 8.8** to overcome any difficulty in obtaining the 5837.

Fig. 8.7. This noise generator, combined with the Fig. 8.6 circuit, provides an exercise in Kalman filter design.



Real-time Kalman filter

The input to the Kalman filter will be a sequence of numbers — actually a string of 1's and 0's from the a-to-d — which represent the noisy transducer output. The operation of the filter will be to process the data sequence in real-time, before presenting the reordered data to the outside world. To simplify the design and description of the digital-signal processing operation, it is customary to adopt the graphical symbols shown in **Fig. 8.9**. Apart from the time-varying gain block $b(n)$ in the feedforward loop, the mathematical operation of each symbolic block should be self-explanatory.

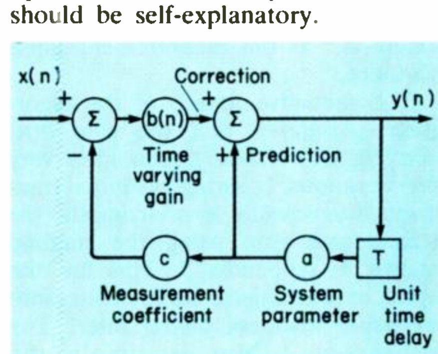
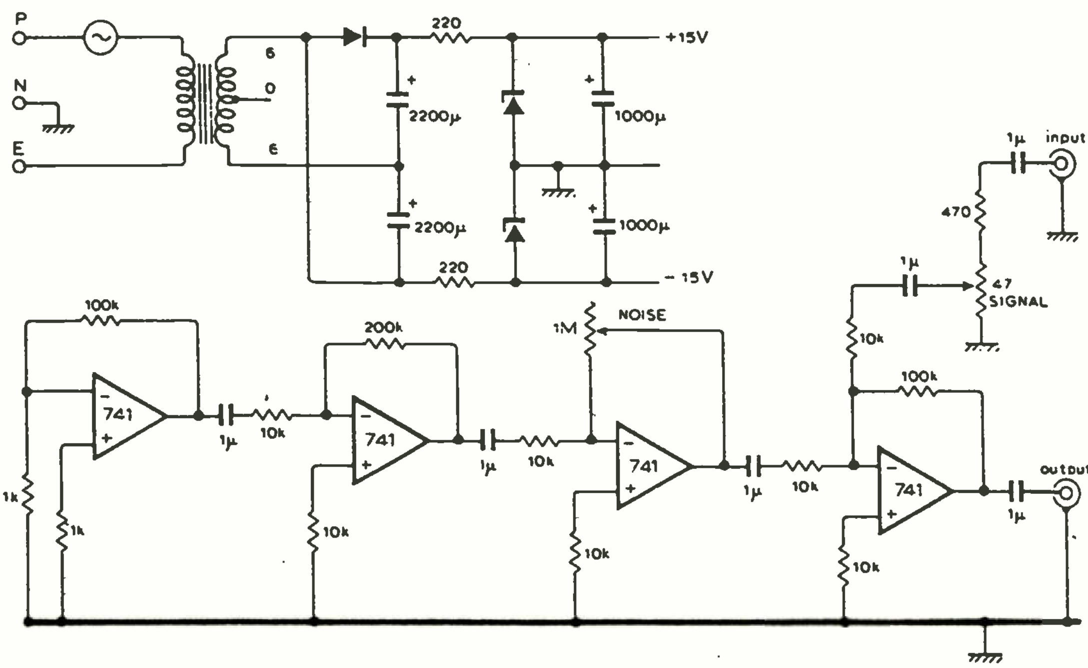


Fig. 8.9. System block diagram of the Kalman filter representing the recursive relationship $\hat{y}(n) = a\hat{y}(n-1) + b(n)[x(n) - ac\hat{y}(n-1)]$.



50–5000 Hz WHITE NOISE—Both signal and noise levels are continuously and independently variable from zero to maximum in simple noise generator developed to demonstrate recovery of low-level 500-Hz signal from noise. Circuit gives maximum noise output into 1500-ohm load; for lower load impedances, reduce noise level to prevent oscillation. Opamps require ±15 V supply, which can be simple voltage doubler without regulation.—J. E. Morris, Simple Noise Generator, *Wireless World*, April 1977, p 62.

Simplifying the design — the steady-state Kalman filter

The Kalman gain is a time-varying parameter whose value cannot exceed unity. The magnitude of the gain reflects the confidence the filter places in the current measurement. When the gain is small, the filter is suspicious of the new data and places more confidence in its prediction. When the gain is large, the filter is less dubious of the new measurement. As shown in the appendix, the gain is related to the error covariance $\rho(n)$, or mean-squared error, in this single variable example by this recursive expression:

$$b(n) = \frac{\rho(n)}{(\rho(n)+\sigma_v^2)}$$

where σ_v^2 is the measurement noise variance.

The recursive nature of the algorithm guarantees that the gain $b(n)$ converges to a steady value after very few iterations. Ignoring any initial transient, it is possible to pre-compute the steady-state gain using the method shown in Appendix 3. This has the effect of reducing the Kalman filter into a simple low-pass digital filter. The processed output is simply the weighted sum of the current noisy input and the previous output. The careful choice of coefficients using the methods outlined in the appendix ensures that any sudden changes in the input will be smoothed out. This will leave only the long-term trend or low-frequency component. Additional insight into the smoothing operation is achieved by convoluting the impulse response $h(n)$ with an input signal $x(n)$. The time-extended impulse response is a reminder that many input samples must be taken into account when forming the current estimate of the processed output. Try cycling a noisy DC signal through the filter and observe how the processor establishes trends.

To understand the reality behind the abstraction of optimal filtering, it is helpful to design and use your own Kalman filter. The results are really quite remarkable. The C program with graphics advertised in listing 1 implements a linear first-order Kalman filter in terms of the characteristics of the AD590 and the sampling interval T. Use the minimised mean-squared error criterion to process the noisy measurement in real-time and display the filtered output on the monitor. The incorporation of a delay loop in the data capture routine establishes a sampling interval of 50ms. This is in agreement with the model and makes the signal-processing operations observable. Appendix 4 should be a useful source of reference when identifying the relevant parameters in the program. The results of my experiences using the program, transducer, and random-noise source are shown in the screen dumps of **Figs. 8.10** to **8.13**.

Listing 1

```
/ ************************************
*     FIRST-ORDER KALMAN FILTER      *
************************************ /
#include<stdio.h>
#include<graph.h>
#include<conio.h>
#define BASE 512
#define START 0
main()
{
int x,y,j;
float word,old,new,input;
unsigned int lower_bits,upper_bits,flag;
outp(BASE,0);
/*------------------------------------------------
              SELECT CHANNEL
------------------------------------------------*/
for(;;)
{
_setvideomode(_DEFAULTMODE);
_setvideomode(_HRES16COLOR);
/*------------------------------------------------
                EGA MODE
------------------------------------------------*/
_clearscreen(_GCLEARSCREEEN);
_setbkcolor(_GRAY);
_moveto(0,199);
_lineto(639,199);
_moveto(0,199);
_lineto(0,0);
/*------------------------------------------------
              DRAW X & Y AXES
------------------------------------------------*/
_settextcolor(3);
_settextposition(4,3);
```

```
_outtext("Temperature (0–100) degrees
Celsius");
/*------------------------------------------------------
COLOUR AND POSITION TEXT
------------------------------------------------------*/
for(x = 0; x <= 639; x++)
{
outp(BASE+1,START);
/*------------------------------------------------------
START CONVERSION
------------------------------------------------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
lower_bits = inp(BASE+2);
upper_bits = inp(BASE+3);
word = ((15 & upper_bits) * 256) + lower_
bits;
input = word/4095;
/*------------------------------------------------------
RECURSIVE KALMAN FILTER EQn.
------------------------------------------------------*/
new = 0.99 * old + 0.009 * input;
y = 200 * (1 – new);
_setcolor(14);
_moveto(x,y);
_lineto(x,y);
old = new;
/*------------------------------------------------------
TIME WASTE TO MAKE SAMPLING
INTERVAL 50ms
------------------------------------------------------*/
for(j = 0; j <= 20000; j++)
{
}
}
getch();
/*------------------------------------------------------
HIT ANY KEY TO REFRESH SCREEN
------------------------------------------------------*/
}
}
```

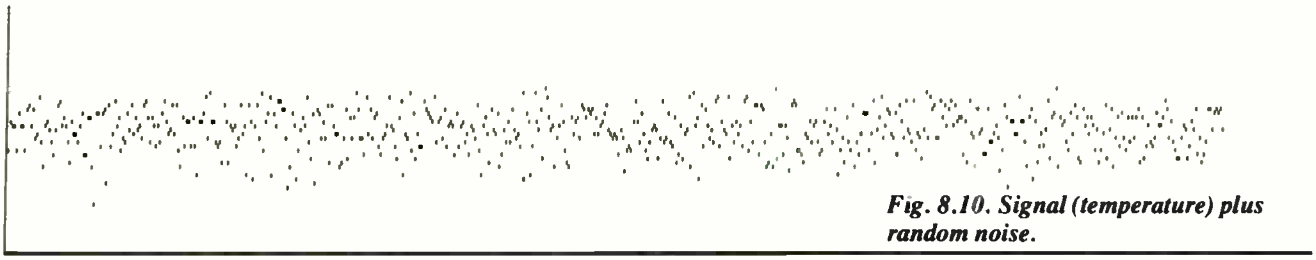


Fig. 8.10. Signal (temperature) plus random noise.

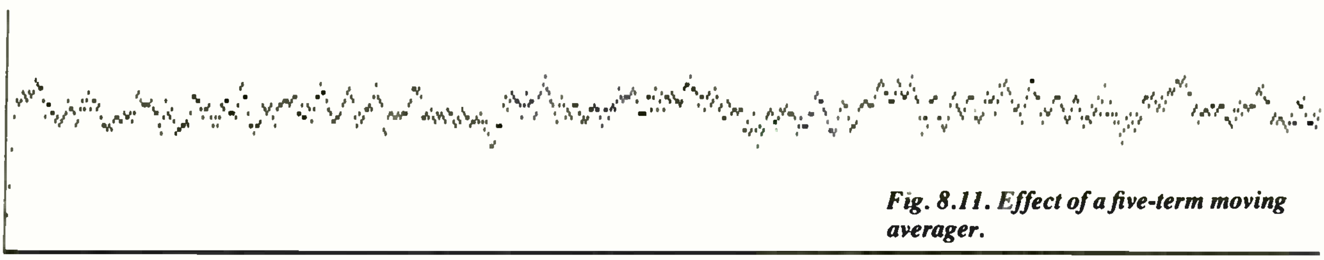


Fig. 8.11. Effect of a five-term moving averager.

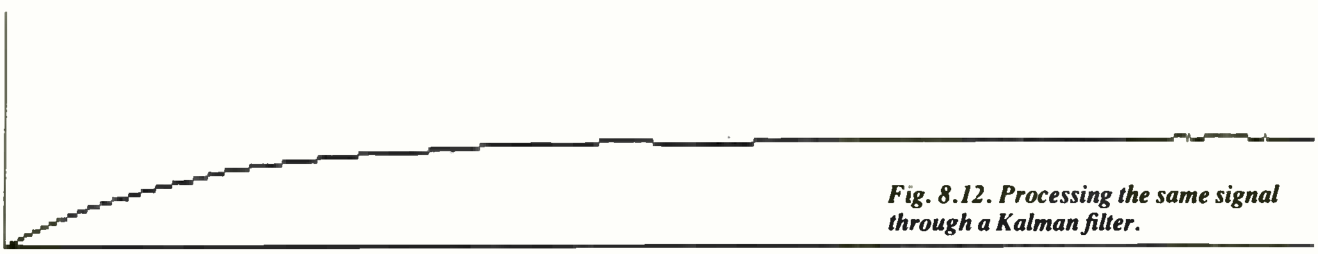


Fig. 8.12. Processing the same signal through a Kalman filter.

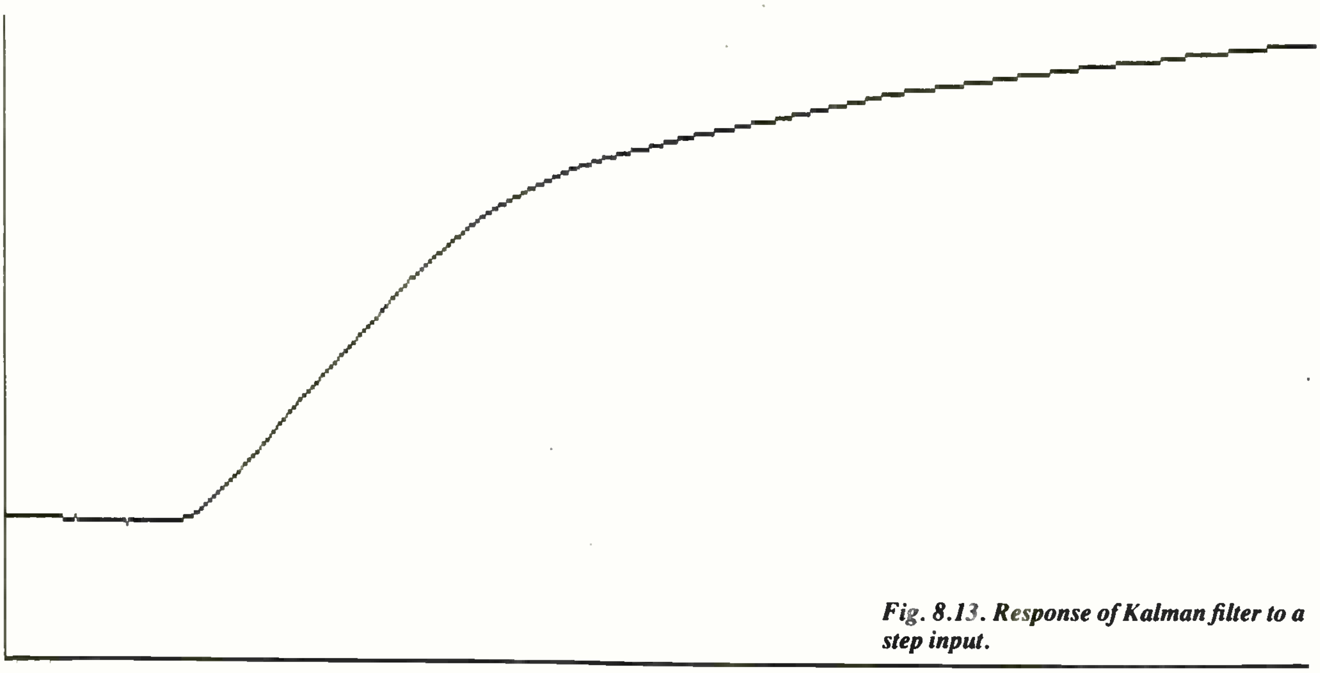


Fig. 8.13. Response of Kalman filter to a step input.

Appendix

(1) Relationship between a(n) and b(n)

The aim is to establish the relationship between the coefficients of the recursive algorithm

$$\hat{y}(n) = a(n)\hat{y}(n-1)+b(n)x(n)$$

Here the first term is a weighted version of the previous "best" estimate, in the sense of the minimised mean-squared error. The second term is a weighted version of the current measurement. Enumeration of the error by

$$e(n) = \hat{y}(n)-y(n)$$

allows the mean-squared error to be written as

$$E[(\hat{y}(n)-y(n))^2]$$

The two time-varying parameters $a(n)$ and $b(n)$ are chosen to minimise the mean-squared error. Write the mean-squared error as:

$$\rho(n) = E[(a(n)\hat{y}(n-1)+b(n)x(n)-y(n))^2]$$

Differentiate with respect to $a(n)$ and $b(n)$ before equating to zero:

$$\frac{\partial\rho(n)}{\partial a(n)} = 2E[a(n)\hat{y}(n-1)+b(n)x(n)-y(n)]\hat{y}(n-1)$$

and

$$\frac{\partial\rho(n)}{\partial b(n)} = 2E[a(n)\hat{y}(n-1)+b(n)x(n)-y(n)]x(n)$$

which is a minimum when

$$a(n)\hat{y}(n-1)+b(n)x(n)-y(n)=0$$

Substitute $x(n) = cy(n)$ to write:

$$a(n) = \frac{y(n)}{\hat{y}(n-1)}[1-cb(n)]$$

since

$$\frac{y(n)}{y(n-1)} = \frac{Y(z)}{Y(z)\,z^{-1}} = z = e^{sT} = a$$

the required relationship is

$$a(n) = a[1-cb(n)]$$

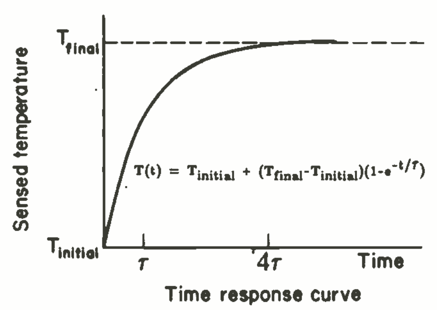
(2) Modelling the dynamic characteristics of the transducer

The mathematical model is based on the Analog Devices AD590 2 terminal IC temperature transducer. For supply voltages between +4V and +30V, the electrical characteristics are equivalent to a constant-current generator producing 1μA/°K. In manufacture, the chips' thin-film resistors are laser-trimmed to calibrate the device to 298.2μA at 298.2°K (+25°C). Due to its high-impedance current output the device is insensitive to voltage drops over long wires, making it ideal for remote-sensing applications. Any well-insulated twisted pair is sufficient for operation 100's of feet from the conditioning circuitry. With reference to Table 8.2, it is possible to model the dynamic characteristics of the transducer using the first-order linear differential equation:

$$\tau\frac{dv}{dt} + v = k(T+w)$$

where τ is the time constant of the transducer in seconds
v is the output voltage in volts
T is the monitored temperature in degrees Celsius (°C)
k is the steady-state gain (0.1)
w is the random white noise

Fig. 8.14. Extract from Analog Devices data sheet. Time response of AD590 to a step change in temperature is determined by thermal resistance and thermal capacities of the chip, C_{CH}, and the case C_C. C_{CH} is about 0.04Ws/°C for the AD590. C_C varies with the measured medium. In most cases, the single time constant exponential curve of Fig. 8.14 is sufficient to describe the time response.



The use of the Laplace transforms allows the deterministic transfer function to be expressed as:

$$\frac{V(s)}{T(s)} = \frac{k}{s\tau+1}$$

Clearly, the pole is located at $s = -1/\tau$. Under the z-mapping $z = e^{sT}$, the pole is translated from the left-hand stable region of the s-plane to a point on the positive real axis of the z-plane located inside the unit circle, where $z = a$. The transfer function of the digital system becomes:

$$H(z) = \frac{k}{z-a}$$

where $a = e^{-T/\tau}$

To obtain the recurrence relationship, convert from transforms to sequences using:

$$\frac{V(z)}{T(z)} = \frac{k}{z-a}$$

cross-multiplying

$$V(z)(z-a) = kT(z)$$

$$v(n+1)-av(n) = kT(n)$$

Expressed in terms of the current output, this is:

$$v(n) = av(n-1)+kT(n-1)$$

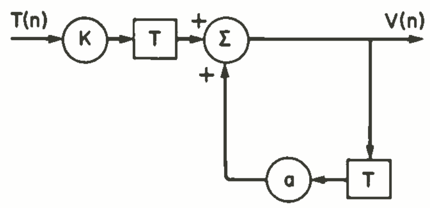


Fig. 8.15. Characteristics of the filter modelled as recursive digital filter.

Rather than apply a deterministic input, enquire how this model will modify the characteristics of white noise. With reference to Fig. 8.15, the sampled output can be expressed as:

$$v(n) = av(n-1)+kw(n-1)$$

The autocorrelation function $r_{vv}(k)$ of the processed output is computed on a sample-by-sample basis using:

$$r_{vv}(k) = E[v(n)\,.v(n+k)]$$

When $k = 0$, the mean-square value of the output noise is:

$$r_{vv}(0) = E[v(n)^2]$$

$$= E[(av(n-1)+kw(n-1))^2]$$

$$= a^2r_{vv}(0)+k^2r_{ww}(0)$$

This may be written as:

$$r_{vv}(0) = \frac{k^2r_{ww}(0)}{1-a^2}$$

To obtain the autocorrelation function, follow this procedure and compute the coefficients for k = 1, 2, 3, . . . etc:

$$r_{vv}(1) = E[v(n)\,.v(n+1)]$$
$$= E[v(n)(av(n)+kw(n))]$$
$$= ar_{vv}(0)$$

Similarly, when $k = 2$:

$$r_{vv}(2) = a^2 r_{vv}(0)$$

Since the ACF is an even function, the coefficients are symmetrical about the origin, as shown in **Fig. 8.16**.

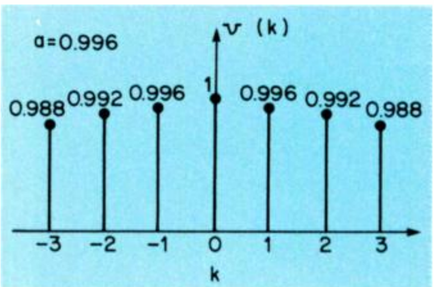


Fig. 8.16. Effect of digital filter on a random input may be determined by autocorrelating the processed output. Notice mean-square value is given by $r_{vv}(0)$.

(3) Evaluating the steady-state gain b(n)

With the aid of the signal and measurement model shown in Fig. 8.17a and the model of the optimum recursive estimator in **Fig. 8.17b**, it is possible to express the mean-squared error as:

$$\rho(n) = E[(\hat{s}(n)-s(n))^2]$$
$$= E[(a\hat{s}(n-1)+b(n)(x(n)-ac\hat{s}(n-1))$$
$$-s(n))^2]$$

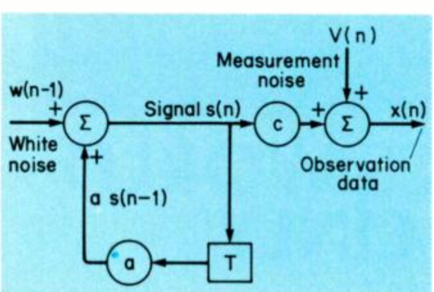
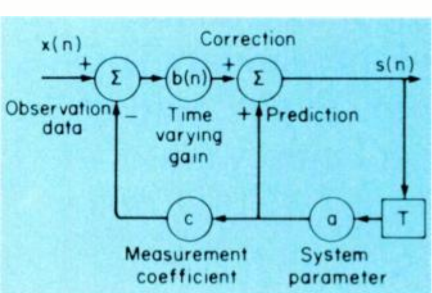


Fig. 8.17. Models of signal and observation process (a) and optimum recursive estimator — Kalman filter (b).



Assume the linear observation model $x(n) = cs(n) + v(n)$ and the dynamic signal model $s(n) = as(n-1) + w(n-1)$. Then substitute and express the mean-squared error as:

$$\rho(n) = E[(a(1-cb(n))e(n-1)$$
$$-(1-cb(n)w(n-1)+b(n)v(n))^2]$$

Because $e(n-1)$, $w(n-1)$ and $v(n)$ share no common characteristic, their averaged cross products or crosscorrelation coefficients will be zero.

$$\rho(n) = a^2[1-cb(n)]^2\rho(n-1)$$
$$+[1-cb(n)]^2\sigma_w^2+b^2(n)\sigma_v^2$$

substituting

$$\rho(n) = \frac{b(n)\sigma_v^2}{c}$$

and rearranging

$$b(n)(\sigma_v^2+c^2[a^2\rho(n-1)+\sigma_w^2])$$
$$= c[a^2\rho(n-1)+\sigma_w^2]$$

Hence the gain of the Kalman filter is given by:

$$b(n) = \frac{c[a^2\rho(n-1)+\sigma_w^2]}{\sigma_v^2+c^2\sigma_w^2+c^2a^2\rho(n-1)}$$

The object of this unpleasant algebra has been to establish the relationship between the steady-state gain b and the parameters a and c. Ignore the initial transient and assume $b(n)$ has converged to a steady value b, when the mean-squared error is a time invariant. This is represented algebraically as

$$\rho(n) = \rho(n-1) = \rho$$

The required result using this relationship is:

$$b^2(a^2c\sigma_v^2)+b(c^2\sigma_w^2+\sigma_v^2[1-a^2])-c\sigma_w^2=0$$

Fig. 8.18. Engineering approximation used to establish standard deviation of random signal.

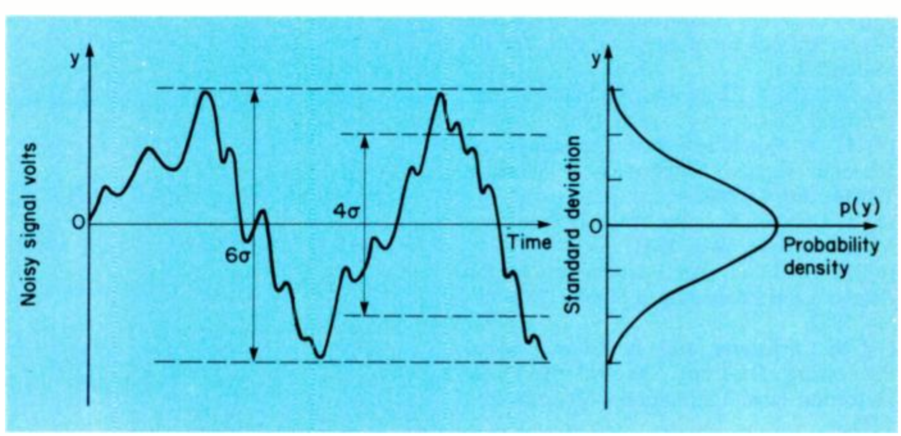
The steady-state gain in achieved by solving the quadratic for b. Of course, this result could have been achieved recursively simply by deducing (remember a deduction is a scientific guess) the initial mean-square error. As an example let $\rho(n-1) = 1000$. This large value indicates low confidence in the deduction, although it does initialise the system and get the filter started. Confirm for yourselves that $b(n)$ approaches the limiting value b after a couple of iterations.

(4) Identifying the parameters

As already indicated, the output from the temperature transducer is a linear voltage with a sensitivity of 100mV/°C. Since 100°C maps to 4095 at the output of the a-to-d (effectively unity after division in the program), select the measurement coefficient c to be 0.01. The numerical value of the sampled signal pole is obtained from the expression $a = e^{-T/\tau}$. With a sampling interval of 50ms and a transducer time constant of 13.5s, this gives $a = 0.9963$. Notice from **Fig. 8.18** that a Gaussian noise voltage spends 99.5% of its entire lifetime within three standard deviations of the mean.

This means that, practically, the overall variation of the noise voltage may be represented by a figure of between four and six standard deviations. Adopt an engineering rule of thumb to allow the standard deviation σ to be interpreted as being $V_{p-p}/5$. It is convenient to estimate the peak-to-peak noisy voltage to be 5V. In other words, the variance σ^2 will be unity. The estimated noise parameters are $\sigma_v^2 = 1$ and $\sigma_w^2 = 1 - a^2 = 0.00738$, which give a steady-state gain b of 0.0098 as well as a Kalman filter equation:

$$y(n) = 0.9963\,y(n-1) + 0.0098[x(n) - 0.009963\,y(n-1)]$$



This may be expressed as an elementary first-order low-pass recursive filter:

$$y(n) = 0.99620y(n-1) + 0.0098x(n)$$

Evidently, this is marginally unstable since $0.99620 + 0.0098 > 1$. However, the Kalman filter is robust and an acceptable compromise is to modify the coefficients as shown:

$$y(n) = 0.99y(n-1) + 0.009x(n)$$

Deliberately detune the filter by adjusting the coefficients and observe the radical change in the processed output. Remember that, theoretically, no other estimator can produce a better estimate of the noisy signal. It is a powerful way of proving that Kalman filters really do reduce the effects of noise. It should also give you the confidence to examine more ambitious projects, using signal vectors and matrix theory.

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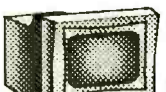

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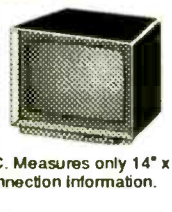

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End of line purchase scoop! Brand new **NEC D2246** 8" 85 megabyte of hard disk storage! Full CPU control and industry standard SMD interface. Ultra hi speed transfer and access time leaves the good old ST506 interface standing. In mint condition and comes complete with manual. Only........................£399(E)

MAINS SUPPRESSORS & FILTERS

Roxburgh SDC 021 2 amp mains RFI filter. Has an extra wide frequency range of 150 khz to 30 mhz. Can type, solder lug connection. Quality manufactured to BS 613 standards. Dims 1-1/2"D x 1-3/4"H.......... £3.95 or 3 for £10 (A) 10 for £28 (B)

Roxburgh SDA 013/25. Similar to above rated at 1-1/2 amps. Dims 1-1/2"D x 1-3/4"H....£3.25 or 3 for £8.50 (A) 10 for £25(B)

Suppression Devices SD5 A10. Extra compact general purpose suppressor. Plastic moulded case with single bolt fixing and snap connectors. Rated at 230 vac 5 amps. Dims 1-3/4"L x 1-1/8"W x 5/8"H..............£3.95 or 3 for £10 (A) 10 for £28 (B)

Belling-Lee type L2127 3 amp mains RFI filters. Has a built in mains cable (English coding), and a three pin miniature non-reversible socket and a mating plug, to go to the equipment. Ideal for those who are bugged by RF interference. Very compact. Dims 3-1/8" x 2.5" x 1.5"..............£3.95 each or 3 for £10 (A)

RECHARGEABLE BATTERIES

LEAD ACID

Maintenance free sealed long life. Type A300.

12 volts	12 volts 3 amp/hours	£13.95(A)
6 volts	6 volts3 amp/hours	£ 9.95(A)
12 volts	Centre tapped 1.8 amp hours. RFE.	£ 5.95(A)
12 volts	12 volts 38 amp hours.7-1/2"L x6"S.RFE	£35.00(B)

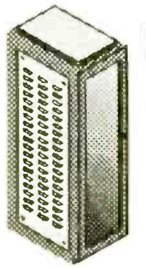
NICKEL CADMIUM

Quality 12v 4ah cell pack. Originally made for the Technicololor video company. Contains 10 GE top quality D nicad cells in a smart robust case with a DC output connector. Ideal for portable equipment. Brand new. £19.95(B)

Ex-equipment NICAD cells by GE. Removed from equipment and in good, used condition: D size 4ah 4 for £5(B) F size 7ah 6 for £8(B)

SPECIAL INTEREST

Tektronix 1751 Waveform/Vector monitor	£2750
Trio 0-18 vdc bench PSU. 30 amps. New	£ 470
DEC VAX11/750 inc. 2 Meg Ram DZ and full documentation, in brand new condition	£3900
Fujitsu M3041 600 LPM band printer	£2950
DEC LS/02 CPU board	£ 150
Calcomp 1036 large drum 3 pen plotter	£ 650
Thurlby LA 160B logic analyser	£ 375
1.5kw 115v 60hz power source	£ 950
Tektronix R140 NTSC TV test signal standard.	£ 875
Sony KTX 1000 Videotex system - **brand new**	£ 790
ADDS 2020 VDU terminals - **brand new**	£ 225
Sekonic SD 150H 18 channel Hybrid recorder	£2000
Trend 1-9-1 Data transmission test set	£ 525
Kenwood DA-3501 CD tester, laser pickup simulator	£ 350



Superb Quality 6 foot 40u 19" Rack Cabinets

Massive Reductions Virtually New, Ultra Smart! *Less Than Half Price!*

Top quality 19" rack cabinets made in UK by Optima Enclosures Ltd. Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the most versatile we have ever sold. Racks may be stacked side by side and therefore require only two side panels or stand singly. Overall dimensions are 77-1/2"H x 32-1/2"D x 22"W. Order as:

Rack 1	Complete with removable side panels	£375.00 (G)
Rack 2	Less side panels	£225.00 (G)

POWER SUPPLIES

Power One SPL200-5200P 200 watt (250 w peak). Semi open frame giving +5v 35a, -5v 1.5a, +12v 4a (8a peak), -12v 1.5a, +24v 4a (6a peak). All outputs fully regulated with over voltage protection on the +5v output. AC input selectable for 110/240 vac. Dims 13" x 5" x 2.5". Fully guaranteed RFE. £85.00 (B)

Power One SPL130. 130 watts. Selectable for 12v (4A) or 24 v (2A). 5v @ 20A. ± 12v @ 1.5A. Switch mode. New. £59.95(B)

Astec AC-8151 40 watts. Switch mode. +5v @ 2.5a. +12v @ 2a. -12v @ 0.1a. 6-1/4" x 4" x 1-3/4".New £19.95(B)

Greendale 19AB0E 60 watts switch mode.+5v @ 6a,±12v @ 1a,±15v @ 1a. RFE and fully tested. 11 x 20 x5.5cms. £24.95(C)

Conver AC130. 130 watt hi-grade VDE spec. Switch mode.+5v @ 15a,-5v @ 1a,±12v @ 6a.27 x 12.5 x 6.5cms.New. £49.95(C)

Boshert 13090. Switch mode. Ideal for drives & system. +5v@ 6a, +12v @ 2.5a, -12v @ 0.5a, -5v @ 0.5a. £29.95(B)

Farnell G6/40A. Switch mode. 5v @ 40a. Encased £95.00(C)

COOLING FANS

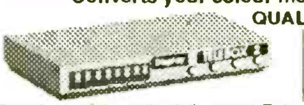
Please specify 110 or 240 volts for AC fans.

3 inch	AC. 1½" thick	£ 8.50(B)
3½ inch	AC ETRI slimline. Only 1" thick.	£ 9.95(B)
4 inch	AC 110/240v 1½" thick.	£10.95(B)
4 inch	AC 1½" thick	£ 9.95(B)
10 inch	AC round. 3½ thick. Rotron 110v	£10.95(B)
10 inch	As above but 230 volts	£24.95(B)
62 mm	DC 1" thick. No.812 for 6/12v.814 24v.	£15.95(A)
80 mm	DC 5 v. Papst 8105G 4w. 38mm. RFE.	£19.95(A)
92 mm	DC 12v. 18 mm thick.	£14.95(A)
4 inch	DC 12v. 12w 1½" thick	£12.50(B)
4 inch	DC 24v 8w. 1" thick.	£14.50(B)

THE *AMAZING* TELEBOX!

Converts your colour monitor into a QUALITY COLOUR TV!!

TV SOUND & VIDEO TUNER!



Brand new high quality, fully cased, 7 channel UHF PAL TV tuner system. Unit simply connects to your TV aerial socket and colour video monitor turning same into a fabulous colour TV. Dont worry if your monitor does'nt have sound, the TELEBOX even has an integral audio amp for driving a speaker plus an auxiliary output for Headphones or Hi Fi system etc. Many other features: LED Status indicator, Smart moulded case, Mains powered, Built to BS safety specs. Many other uses for TV sound or video etc. Supplied BRAND NEW with full 1 year guarantee.

Telebox ST for composite video input monitors	£29.95(B)
Telebox STL as ST but with integral speaker	£34.95(B)
Telebox RGB for analogue RGB monitors	£65.95(B)

RGB Telebox also suitable for IBM multisync monitors with RGB analog and composite sync. Overseas versions VHF & UHF call. SECAM / NTSC not available.

BRAND NEW PRINTERS

TEC Starwriter Model FP1500-25 daisywheel printer renowned for its reliability. Diablo type print mechanism gives superb registration and quality. On board microprocessor gives full Diablo/Qume command capability. Serial RS 232C with full handshake. Bidirectional 25 cps, switchable 10 or 12 pitch, 136 cpl in Pica, 163 in Elite. Friction or tractor feed. Full ASCII including £ sign. Font and ribbon Diablo compatible........£199(E)

DED DPG21 miniature ball point pen printer plotter mechanism with full 40 characters per line. Complete with data sheet which includes circuit diagrams for simple driver electronics......£49(B)

Centronics 150 series. Always known for their reliability in continuous use - real workhorses in any environment. Fast 150 cps with 4 fonts and choice of interfaces at a fantastic price!

150-4 Serial up to 9.5" paper, fan fold tractor	£ 99.00(E)
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152-2 parallel up to 14.5" paper, tractor or s/sheet	£149.00(E)

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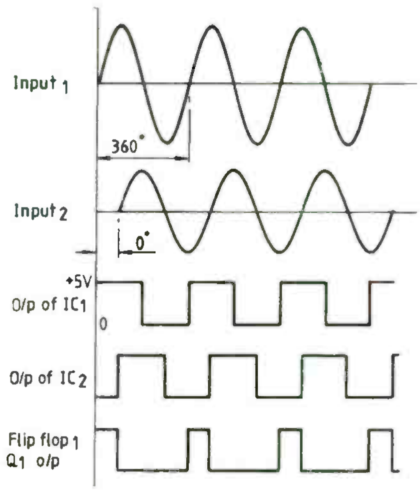
Low-cost digital phasemeter

To make a phase meter with a typical error of 0.2%, the ICL 7107 digital voltmeter IC can be pressed into service to display the phase difference of two signals in degrees.

Two LM311 comparators convert the inputs to cmos-compatible square waves. The leading edge of the square at IC_1 output sets FF_1 and removes the inhibit from FF_2, that from U_2 setting FF_2 which resets FF_1, FF_2 in turn being reset. Output at Q_1 is therefore a pulse whose width is directly proportional to phase difference between the inputs.

Resistors R_5 and R_6 form a voltage divider to provide a voltage reference of 1.02V for the ICL7107, the height of the pulses from Q_1 being set by R_3 and R_4 to $3.6V_{ref}$ at position 1 of the range switch. The average voltage of the pulse train is ($3.6V_{ref}$ x duty cycle) and the display reads (1000 x average/v_{ref}), which is 3600 x phase difference/360°, or 10 x phase difference.

The decimal point of the display is arranged to give a reading in degrees, so that the resolution is 0.1° over the range 0-199.9. For the range set by resistors $R_{1,2}$, measurement resolution is 1° over 0-360°. Measurement accuracy is better than 0.2% over 1kHz to 250kHz, falling off at lower frequencies.

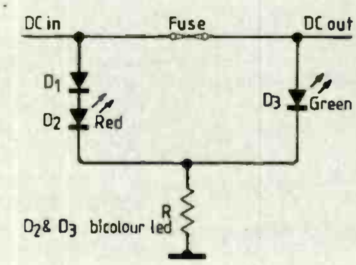


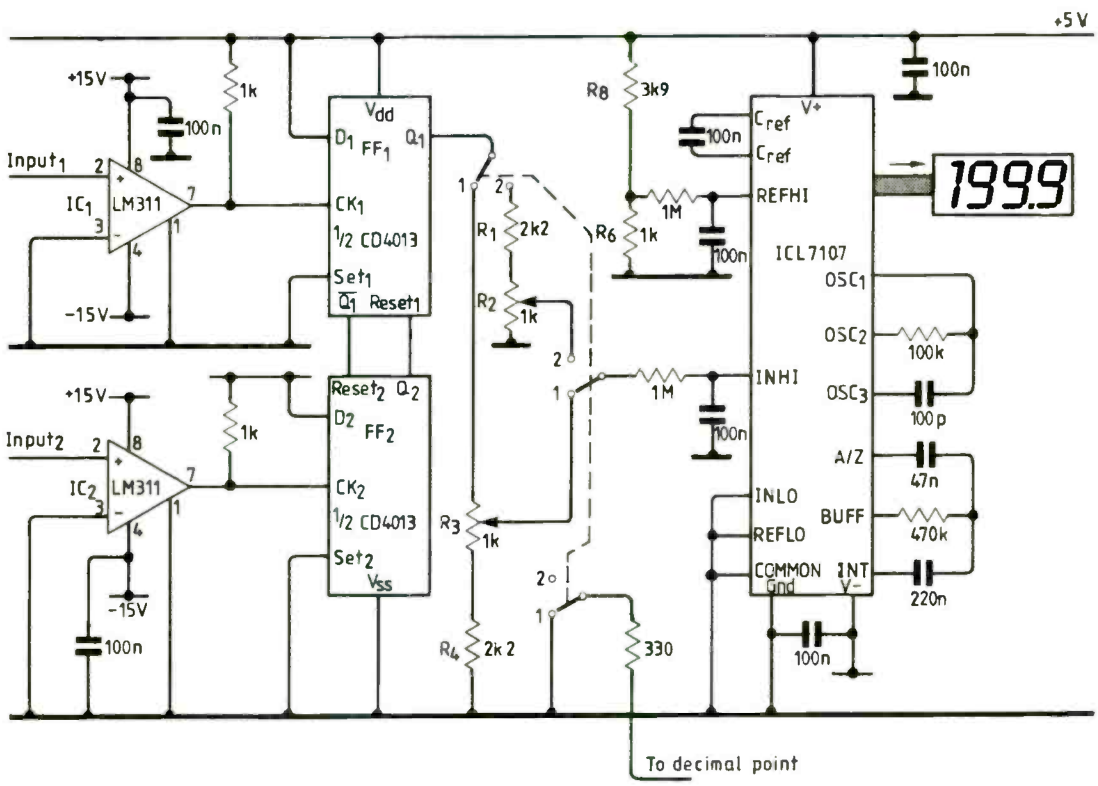
M.S. Nagaraj
ISRO Satellite Centre
Bangalore India

"Fuse-blown" indicator

When the fuse blows, Led1 indicates the fact. Normally, the red led, D_1, is in parallel with the green led D_2, the voltage drop across D_1 preventing Led_1 from illuminating. A blown fuse removes the current through Led_2, the voltage across Led_1 allowing it to light. Resistor $R=DC_{in}/0.01$, unless DC_{in} is 5V, in which case R=470Ω.

T. Cottignoli
Taranto, Italy





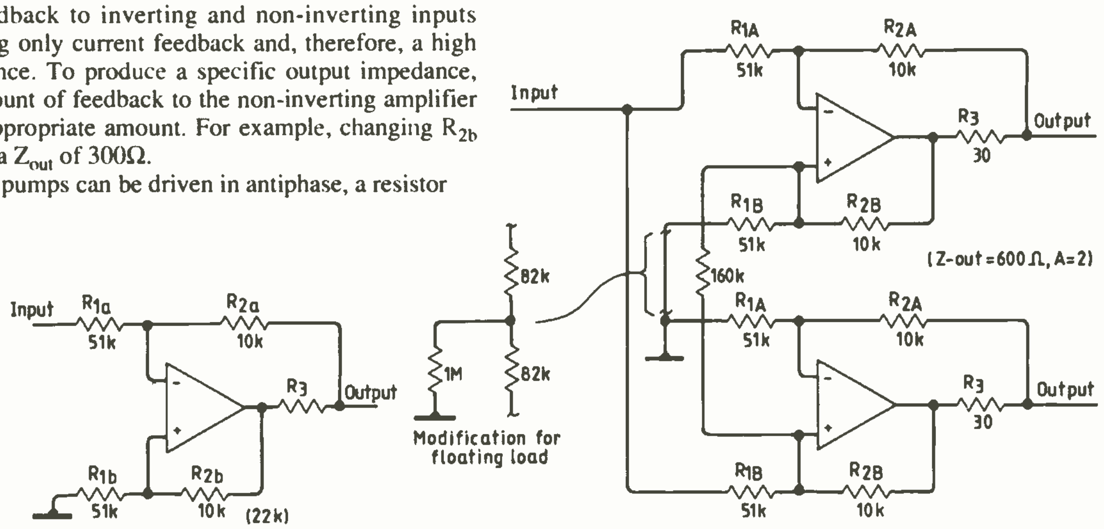
Composite-feedback amplifier

An amplifier with a defined output impedance can be implemented rather more easily than in the circuit given by A.J. Chamberlain in the October 1989 Circuit Ideas by the use of a modified version of the Howland current-pump circuit shown left.

Voltage feedback to inverting and non-inverting inputs cancels, leaving only current feedback and, therefore, a high output impedance. To produce a specific output impedance, reduce the amount of feedback to the non-inverting amplifier input by the appropriate amount. For example, changing R_{2b} to 22kΩ gives a Z_{out} of 300Ω.

Two current pumps can be driven in antiphase, a resistor being connected between the non-inverting inputs to produce an amplifier with a floating output giving +24dB with 24V rails and +16dB with 6V rails.

D. Austin
Birmingham



Battery life extender

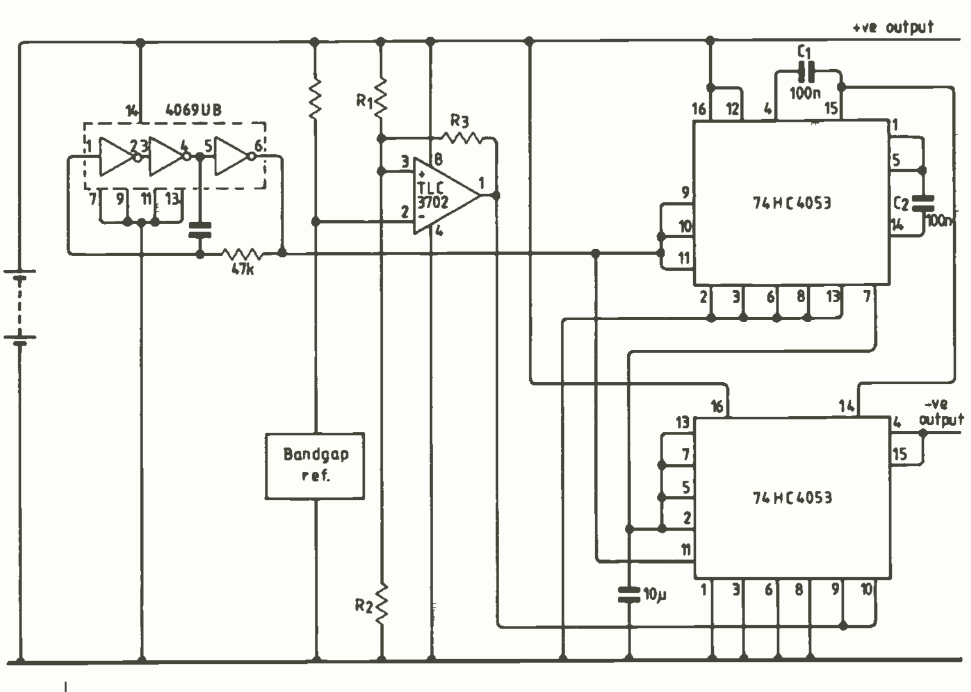
Since primary batteries are usually discarded when their output voltage has dropped below about two thirds of the initial voltage, any means of reducing the consequent waste of money and resources is worth considering. The problem is to ensure that the performance of battery-powered equipment does not suffer at a reduced battery voltage.

In this circuit, a TLC3702 comparator senses when the battery output has reached a level determined by R_1/R_2; resistor R_3 provides a degree of positive feedback to avoid oscillation. At this point, the three-gate oscillator driving a 74HC4053 capacitive multiplier increases the output to 150% of the battery voltage, which enables the battery to continue in service until its voltage has dropped to less than 50%.

The multiplier is similar to the 7660 capacitive doubler but, instead of charging a capacitor and placing it series with the battery. Two capacitors (C_1 and C_2 are charged in series and placed in series with the battery but in parallel with each other. Although the oscillator shown runs at around 100kHz, frequency is not important, C_1 and C_2 being adjusted to suit.

Efficiency of the circuit is about 90% at 2mA, falling to 80% at 5mA. Several switch packages can be used in parallel to improve efficiency.

Ian M. Wiles
IPR Technology
Basingstoke
Hampshire



REAL POWER AMPLIFIER For your car, it has 150 watts output. Frequency response 20HZ to 20 KHZ and a signal to noise ratio better than 60db. Has builtin short circuit protection and adjustable input level to suit youe existing car stereo, so needs no pre-amp. Works into speakers ref 30P7 described below. A real bargain at only £57.00 Order ref 57P1.

REAL POWER CAR SPEAKERS. Stereo pair output 100w each. 4ohm impedance and consisting of 6 1/2" woofer 2" mid range and 1" tweeter. Ideal to work with the amplifier described above. Price per pair £30.00 Order ref 30P7.

PERSONAL STEREOS Customer returns but complete with a pair of stereo headphones very good value at £3.00 ref 3P83. We also have customer returned units with a built in FM radio at £6.00 ref 6P34

2KV 500 WATT TRANSFORMERS Suitable for high voltage experiments or as a spare for a microwave oven etc. 250v AC Input. £10.00 ref 10P93

MICROWAVE CONTROL PANEL. Mains operated, with touch switches. Complete with 4 digit display, digital clock, and 2 relay outputs one for power and one for pulsed power (programmable). Ideal for all sorts of precision timer applications etc. £6.00 ref 6P18

FIBRE OPTIC CABLE. Stranded optical fibres sheathed in black PVC. Five metre length £7.00 ref 7P29

12V SOLAR CELL. 200mA output ideal for trickle charging etc. 300 mm square. Our price £15.00 ref 15P42

PASSIVE INFRA-RED MOTION SENSOR. Complete with daylight sensor, adjustable lights on timer (8 secs -15 mins), 50' range with a 90 deg coverage. Manual override facility. Complete with wall brackets, bulb holders etc. Brand new and guaranteed. £25.00 ref 25P24.

Pack of two PAR38 bulbs for above unit £12.00 ref 12P43

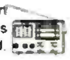
VIDEO SENDER UNIT. Transmit both audio and video signals from either a video camera, video recorder or computer to any standard TV set within a 100' range! (tune TV to a spare channel). 12v DC op. £15.00 ref 15P39 Suitable mains adaptor £5.00 ref 5P191

FM TRANSMITTER housed in a standard working 13A adapter (bug is mains driven). £18.00 ref 18P10

MINATURE RADIO TRANSCEIVERS. A pair of walkie talkies with a range of up to 2 kilometres. Units measure 22x52x155mm. Complete with cases. £30.00 ref 30P12

FM CORDLESS MICROPHONE. Small hand held unit with a 500' range! 2 transmit power levels reqs PP3 battery. Tuneable to any FM receiver. Our price £15 ref 15P42

10 BAND COMMUNICATIONS RECEIVER. 7 short bands, FM, AM and LW DX/local switch, tuning 'eye' mains or battery. Complete with shoulder strap and mains lead. £34.00 ref 34P1



WHISPER 2000 LISTENING AID. Enables you to hear sounds that would otherwise be inaudible! Complete with headphones. Cased. £5.00 ref 5P179.

CAR STEREO AND FM RADIO. Low cost stereo system giving 5 watts per channel. Signal to noise ratio better than 45db, wow and flutter less than .35%. Neg earth. £25.00 ref 25P21.

LOW COST WALKIE TALKIES. Pair of battery operated units with a range of about 150'. Our price £8.00 a pair ref 8P50

7 CHANNEL GRAPHIC EQUALIZER plus a 60 watt power amp! 20-21KHZ 4-8R 12-14v DC negative earth. Cased. £25 ref 25P14.

NICAD BATTERYS. Brand new top quality. 4 x AA's £4.00 ref 4P44. 2 x C's £4.00 ref 4P73, 4 x D's £9.00 ref 9P12, 1 x PP3 £6.00 ref 6P35

TOWERS INTERNATIONAL TRANSISTOR SELECTOR GUIDE. The ultimate equivalents book. Latest edition £20.00 ref 20P32.

CABLE TIES. 142mm x 3.2mm white nylon pack of 100 £3.00 ref 3P104. Bumper pack of 1,000 ties £14.00

BUILD AN IBM COMPATIBLE PC !

AT 12 meg turbo 286 mother board.	£115.00	pc1
1 meg memory for above board.	£55.00	pc2
4 meg memory for above board.	£214.00	pc3
AT keyboard	£49.00	pc4
AT power supply and pc case (complete)	£115.00	pc5
AT controller card with 2 x serial, 1 x parallel Floppy and hard controller + mono Display driver.	£74.00	pc6
1.2 meg 3 1/2" disc drive.	£74.00	pc7
1.44 meg 5 1/4" drive.	£66.00	pc8
Amber monitor 12"	£99.00	pc9
40 meg hard disc.	£270.00	pc10
100 meg hard disc.	£595.00	pc11

minimum system consisting of mother board, 1 meg of memory, case, power supply, 1.44 meg floppy, Interfaces, and monitor is

£525.00 inc VAT (single drive mono 286)	pc12
£795.00 inc VAT (40 meg + floppy + mono 286)	pc13

1991 CATALOGUE AVAILABLE NOW IF YOU DO NOT HAVE A COPY PLEASE REQUEST ONE WHEN ORDERING OR SEND US A 6"X9" SAE FOR A FREE COPY.

GEIGER COUNTER KIT. Complete with tube, PCB and all components to build a battery operated geiger counter. £39.00 ref 39P1

FM BUG KIT. New design with PCB embedded coil. Transmits to any FM radio. 9v battery req'd. £5.00 ref 5P158

TV SOUND DECODER. Nicely cased unit, mains powered 8 channel will drive a small speaker directly or could be fed into HI FI etc. Our price £12.00 ref 12P22

COMPOSITE VIDEO KITS. These convert composite video into separate H sync, V sync and video. 12v DC. £8.00 ref 8P39.

SINCLAIR C5 MOTORS 12v 29A (full load) 3300 rpm 6"x4" 1/4" O/P shaft. New. £20.00 ref 20P22.

As above but with fitted 4 to 1 inline reduction box (800rpm) and toothed nylon belt drive cog £40.00 ref 40P8.

SINCLAIR C5 WHEELS 13" or 16" dia including treaded tyre and inner tube. Wheels are black, spoked one piece poly carbonate. 13" wheel £6.00 ref 6P20, 16" wheel £6.00 ref 6P21.

ELECTRONIC SPEED CONTROL KIT for c5 motor. PCB and all components to build a speed controller (0-95% of speed). Uses pulse width modulation. £17.00 ref 17P3.

SOLAR POWERED NICAD CHARGER. Charges 4 AA nicads in 8 hours. Brand new and cased £6.00 ref 6P3.

MOSFETS FOR POWER AMPLIFIERS ETC. 100 watt mosfet pair 2SJ99 and 2SK343 £4.00 a pair with pin out info ref 4P51. Also available is a 2SK413 and a 2SJ118 at £4.00 ref 4P42

10 MEMORY PUSH BUTTON TELEPHONES. These are 'customer returns' so they may need slight attention. BT approved. £6.00 each ref 6P16 or 2 for £10.00 ref 10P77.

12 VOLT BRUSHLESS FAN 4 1/2" square brand new ideal for boat, car, caravan etc. £8.00 each ref 8P26.

acorn data recorder ALF503. Made for BBC computer but suitable for others. Includes mains adapter, leads and book. £15.00 ref 15P43

VIDEO TAPES. Three hour superior quality tapes made under licence from the famous JVC company. Pack of 10 tapes £20.00 ref 20P20.

ELECTRONIC SPACESHIP. Sound and impact controlled, responds to claps and shouts and reverses when it hits anything. Kit with complete assembly instructions £10.00 ref 10P81.

PHILIPS LASER. 2MW HELIUM NEON LASER TUBE. BRAND NEW FULL SPEC £40.00 REF 40P10. MAINS POWER SUPPLY KIT £20.00 REF 20P33 READY BUILT AND TESTED LASER IN ONE CASE £75.00 REF 75P4.

SWITCHED MODE POWER SUPPLY (Boshert) +5 at 15A, +12 at 3A, -12 at 2A, +24 at 2A. 220 or 110v Input. Brand new £20.00 ref 20P30.

SOLDER 22SWG resin cored solder on a 1/2kg reel. Top quality. £4.00 a reel ref 4P70.

600 WATT HEATERS. Ideal for air or liquid, will not corrode, lasts for years. coil type construction 3"x2" mounted on a 4" dia metal plate for easy fixing. £3.00 ea ref 3P78 or 4 for £10.00 ref 10P76.

TIME AND TEMPERATURE MODULE. A clock, digital thermometer (Celcius and Farenheit (0-160 deg F) programmable too hot and too cold alarms. Runs for at least a year on one AA battery. £9.00 ref 9P5.

Remote temperature probe for above unit £3.00 ref 3P60.

GEARBOX KITS. Ideal for models etc. Contains 18 gears (2 of each size) 4x50mm axles and a powerful 9-12v motor. All the gears etc are push fit. £3.00 for complete kit ref 3P93.

ELECTRONIC TICKET MACHINES. These units contain a magnetic card reader, two matrix printers, motors, sensors and loads of electronic components etc. (12"x12"x7") Good value at £12.00 ref 12P28.

JOYSTICKS. Brand new with 2 fire buttons and suction feet these units can be modified for most computers by changing the connector etc. Price is 2 for £5.00 ref 5P174.

QUALITY PANEL METERS. 50uA movement with 3 different scales that can be brought into view with a lever! £3.00 each ref 3P81.

CAR IONIZER KIT. Improve the air in your car! clears smoke and helps to reduce fatigue. Case required. £12.00 ref 12P8.

METAL DETECTOR. Fun light weight device for buried treasure! 33" long with tune and fine tune controls. £10.00 ref 10P101.

6V 10AH LEAD ACID sealed battery by yuasha ex equipment but in excellent condition now only 2 for £10.00 ref 10P95.

12 TO 220V INVERTER KIT. As supplied it will handle up to about 15 w at 220v but with a larger transformer it will handle 100 watts. Basic kit £12.00 ref 12P17. Larger transformer £12.00 ref 12P41.

VERO EASI WIRE PROTOTYPING SYSTEM. Ideal for designing projects on etc. Complete with tools, wire and reusable board. Our price £6.00 ref 6P33.

MICROWAVE TURNTABLE MOTORS. Complete with weight sensing electronics that would have varied the cooking time. Ideal for window displays etc. £5.00 ref 5P165.

STC SWITCHED MODE POWER SUPPLY 220v or 110v input giving 5v at 2A, +24v at 0.25A, +12v at 0.15A and +90v at 0.4A £12.00 ref 12P27.

CAMERA FLASH UNITS. Require a 3v DC supply to flash. £2.00 each ref 2P38 or 6 for £10.00 ref 10P101 (ideal multi-flash photography).

TELEPHONE AUTODIALLERS. These units, when triggered will automatically dial any telephone number. Originally made for alarm panels. BT approved. £12.00 ref 12P23 (please state telephone no req'd).

25 WATT STEREO AMPLIFIER ic. STK043. With the addition of a handful of components you can build a 25 watt amplifier. £4.00 ref 4P69 (Circuit dia included).

MINATURE DOT MATRIX PRINTER assembly 24 column 5v (similar to RS type). £10.00 each ref 10P92.

LINEAR POWER SUPPLY Brand new 220v input +5 at 3A, +12 at 1A, -12 at 1A. Short circuit protected. £12.00 ref 12P21.

MAINS FANS. Snail type construction. Approx 4"x5" mounted on a metal plate for easy fixing. New £5.00 5P166.

POWERFUL IONIZER KIT. Generates 10 times more ions than commercial units! Complete kit including case £18.00 ref 18P2.

MINI RADIO MODULE. Only 2" square with ferrite aerial and tuner. Superhet. Req's PP3 battery. £1.00 ref BD716.

HIGH RESOLUTION MONITOR. 9" black and white Phillips tube in chassis made for OPD computer but may be suitable for others. £20.00 ref 20P26.

SURFACE MOUNT KIT. Makes a high gain snooping amplifier on a PCB less than an inch square! £7.00 ref 7P15.

SURFACE MOUNT SOLDER. In easy to use tube. Ideal for above project £12.00 ref 12P18.

CB CONVERTORS. Converts a car radio into an AM CB receiver. Cased with circuit diagram. £4.00 ref 4P48

FLOPPY DISCS. Pack of 15 31/2" DSDD £10.00 ref 10P88. Pack of 10 51/4" DSDD £5.00 ref 5P168.

SONIC CONTROLLED MOTOR. One click to start, two click to reverse direction, 3 click to stop! £3.00 each ref 3P137.

FRESNEL MAGNIFYING LENS. 83 x 52mm £1.00 ref BD827.

lcd display. 4 1/2 digits supplied with connection data £3.00 ref 3P77 or 5 for £10.00 ref 10P78.

TRANSMITTER AND RECEIVER. These units were designed for nurse call systems and transmit any one of 16 different codes. The transmitter is cased and designed to hang round the neck. £12.00 a pair ref 12P26.

ALARM TRANSMITTERS. No data available but nicely made complex transmitters 9v operation. £4.00 each ref 4P81.

100M REEL OF WHITE BELL WIRE. figure 8 pattern ideal for intercoms, door bells etc £3.00 a reel ref 3P107.

ULTRASONIC LIGHT. This battery operated unit is ideal for the shed etc as it detects movement and turns a light on for a preset time. (light included). Could be used as a sensor in an alarm system. £14.00 each ref 14P8.

CLAP LIGHT. This device turns on a lamp at a finger 'snap' etc. £4.00 each ref 4P82.

ELECTRONIC DIPSTICK KIT. Contains all you need to build an electronic device to give a 10 level liquid indicator. £5.00 (ex case) ref 5P194.

UNIVERSAL BATTERY CHARGER. Takes AA's, C's, D's and PP3 nicads. Holds up to 5 batteries at once. New and cased, mains operated. £6.00 ref 6P36.

ONE THOUSAND CABLE TIES! 75mm x 2.4mm white nylon cable ties only £5.00 ref 5P181.

HI-FI SPEAKER. Full range 131mm diameter 8 ohm 60 watt 63-20 khz excellent reprduction. £12.00 ref 12P33.

ASTEC SWITCHED MODE POWER SUPPLY. 80mm x 165mm (PCB size) gives +5 at 3.75A, +12 at 1.5A, -12 at 0.4A. Brand new £12.00 ref 12P39.

VENTILATED CASE FOR ABOVE PSU with IEC filtered socket and power switch. £5.00 ref 5P190.

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CUSTOMER RETURNED switched mode power supplies. Mixed type, good for spares or repair. £2.00 each ref 2P292.

DRILL OPERATED PUMP. Fits any drill and is self priming. £3.00 ref 3P140.

PERSONAL ATTACK ALARM. Complete with built in torch and vanity mirror. Pocket sized, req's 3 AA batteries. £3.00 ref 3P135

POWERFUL SOLAR CELL 1AMP .45 VOLT! only £5.00 ref 5P192 (other sizes available in catalogue).

SOLAR PROJECT KIT. Consists of a solar cell, special DC motor, plastic fan and turntables etc plus a 20 page book on solar energy! Price is £8.00 ref 8P51.

RESISTOR PACK. 10 x 50 values (500 resistors) all 1/4 watt 2% metal film. £5.00 ref 5P170.

CAPACITOR PACK 1. 100 assorted non electrolytic capacitors £2.00 ref 2P286.

CAPACITOR PACK 2. 40 assorted electrolytic capacitors £2.00 ref 2P287.

QUICK CUPPA? 12v immersion heater with lead and cigar lighter plug £3.00 ref 3P92.

LED PACK. 50 red leds, 50 green leds and 50 yellow leds all 5mm £8.00 ref 8P52

12 " HIGH RESOLUTION MONITOR. AMBER SCREEN BEAUTIFULLY CASED NEEDS 12V AT 1A TTL INPUT (SEP SYNCS). £22.00 REF 22P2.

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FERRARI TESTAROSSA. A true 2 channel radio controlled car with forward, reverse, 2 gears plus turbo. Working headlights. £22.00 ref 22P6.

SUPER FAST NICAD CHARGER. Charges 4 AA nicad's in less than 2 hours! Plugs into standard 13A socket. Complete with 4 AA nicad batteries £16.00 ref 16P8.

ULTRASONIC WIRELESS ALARM SYSTEM. Two units, one a sensor which plugs into a 13A socket in the area you wish to protect. The other, a central alarm unit plugs into any other socket elsewere in the building. When the sensor is triggered (by body movement etc) the alarm sounds. Adjustable sensitivity. Price per pair £20.00 ref 20P34. Additional sensors (max 5 per alarm unit) £11.00 ref 11P6.

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WASHING MACHINE PUMP. Mains operated new pump. Not self priming. £5.00 ref 5P18.

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QUICK FIX MAINS CONNECTOR. Ideal for the fast connection of mains equipment. Neon indicator and colour coded connectors. £7.00 ref 7P18.

COPPER CLAD STRIP BOARD 17" x 4" of .1" pitch "vero" board. £4.00 a sheet ref 4P62 or 2 sheets for £7.00 ref 7P22.

STRIP BOARD CUTTING TOOL. £2.00 ref 2P352.

3 1/2" disc drive. 720K capacity made by NEC £60.00 ref 60P2

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TV LOUDSPEAKERS. 3 watt 8 ohm magnetically screened 70 x 50mm. £3.00 a pair ref 3P108.

TOROIDAL TRANSFORMER. 24v 5A encapsulated 4" dia £5.00 ref 5P34.

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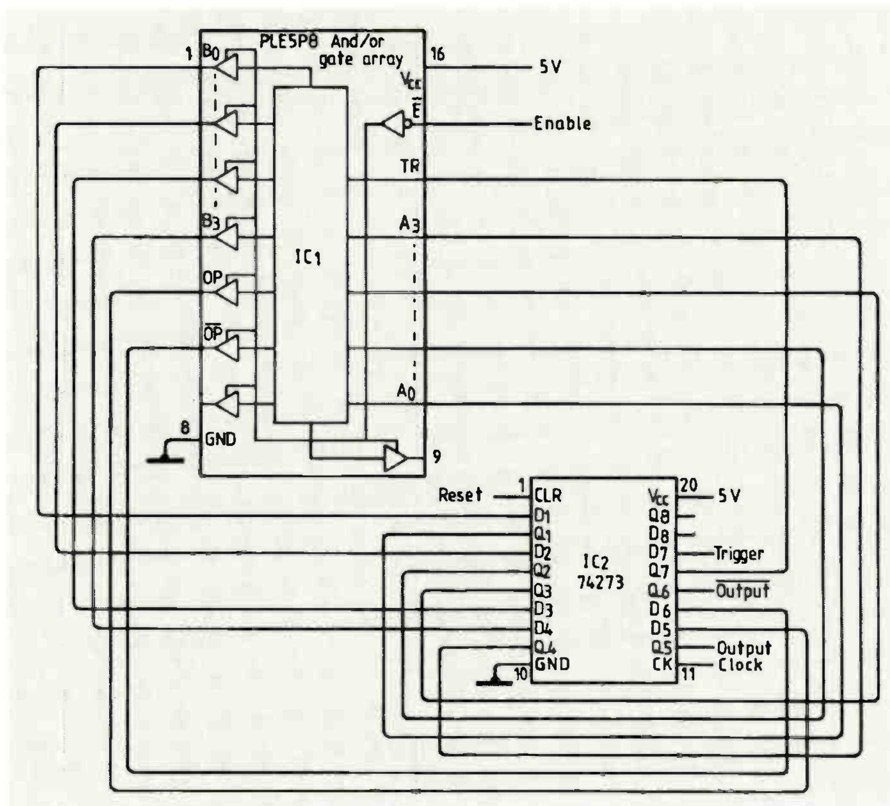
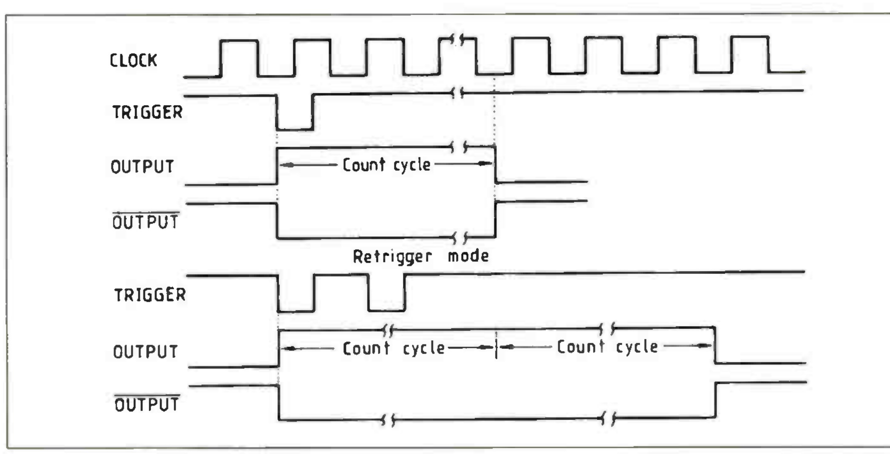


Programmable pulse generators commonly have limited programming capability and exhibit initial timing error caused by lack of synchronism between the input trigger and the system clock. The circuit described overcomes these disadvantages. No RC timing is used and accuracy is solely dependent on clock frequency; a wide range of pulse widths is obtained by changing the clock frequency.

A PLE5P8 programmable logic element by Monolithic Memories and a 74273 octal latch compose the circuit; the clock input to the 74273 may be the system clock. Four of the five inputs to the PLE are used for state-incrementing control, the fifth serving as the trigger. The clear input of the latch functions as the reset input for the generator. Both active-high and active-low outputs are available.

When the trigger goes low, the true output of the generator goes high and begins to time-out the programmed n clock cycles; after one complete cycle, the true output goes low. In the case of re-triggering, timing continues for another n cycles and, if re-triggering continues, so does the output timing.

In the circuit shown, from 1 to 16 clock cycles can be programmed at any desired frequency, and a PLD with more inputs will allow a greater selection of timing combinations; a PLD with nine inputs will give 1 to 256 clock cycles, one input being used as the trigger input.

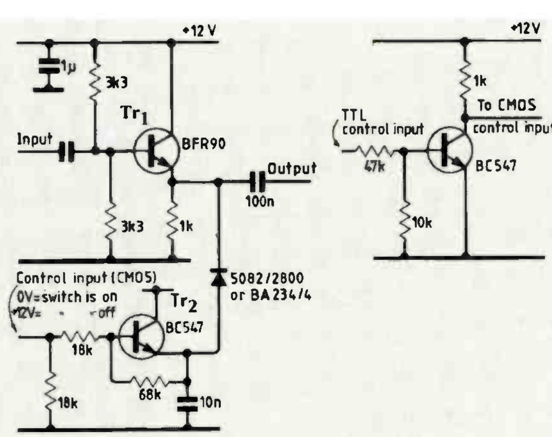


V.Lakshminarayanan
Centre for Development of Telematics
Bangalore
India

High frequency switch

An emitter follower can be used as an RF switch, which will work at VHF, with a high switching speed.

Transistor Tr_1 is an emitter follower and Tr_2 a current switch. A voltage of 0V at the control input cuts off Tr_2 and therefore D_1, allowing Tr_1 to function as an emitter follower. When the control voltage is 12V, Tr_2 is on, D_1 conducts and cuts Tr_1 off, preventing signal reaching the output. Attenuation in this condition is greater than -30dB at 80MHz. The control input is cmos-compatible, but the circuit shown right can be used to make the circuit usable for TTL input.



D.I Malynovsky
Leningrad USSR

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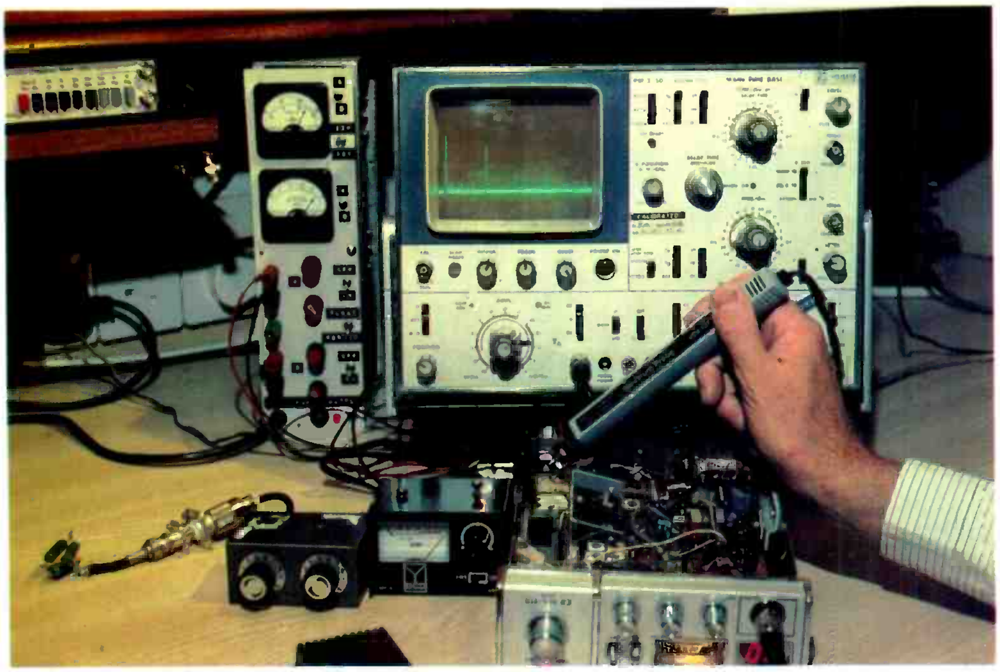
USE YOUR SCOPE AS A SPECTRUM ANALYSER FOR JUST £295

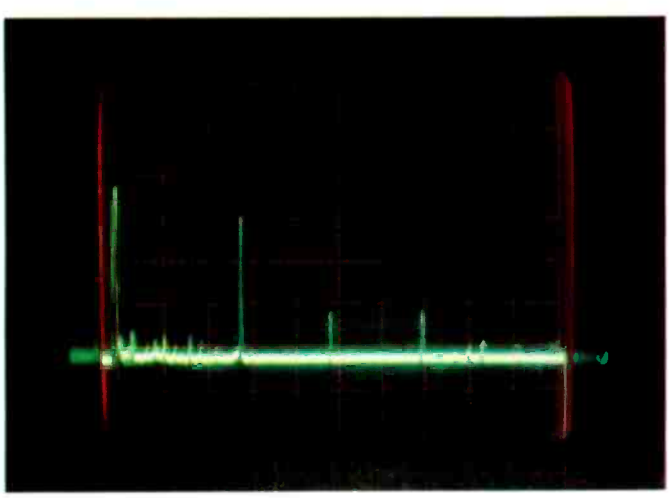


Imagine, if you will, an instrument which offers the power of a spectrum analyser combined with the ease of use of a conventional oscilloscope probe. Hard to imagine? Not any more. The Type 107 Spectrum Probe from Laplace Instruments provides these facilities at a mere fraction of the cost of a fully-fledged spectrum analyser.

Specifications. Laplace Instruments quote the following specifications for the Type 107 Spectrum Probe

FREQUENCY RANGE: 100MHz
DYNAMIC RANGE: 50dB min.
VERTICAL OUTPUT: 5mV/dB typical
VERTICAL LOGARITHMIC LINEARITY: ±3dB
TANGENTIAL SENSITIVITY: 100µV ±3dB at 50MHz
FLATNESS: ±2dB, 5MHz to 100MHz
LF DEGRADATION: Approx. 5dB down below 1MHz
SPURIOUS RESPONSES: Generallly -40dB
IF BANDWIDTH: 180kHz at -3dB
MAX CW INPUT: +15dBm, 1V at 100MHz
SWEEP RATE: 6ms/100MHz typical
HORIZONTAL LINEARITY: ±10%
RADIATION (FROM PROBE TIP): -40dBm at 150MHz
POWER SOURCE: 220V ±10% 50Hz 4W max.
SIZE: 190 x 25mm diam. (probe)
WEIGHT: 56gm (probe) 260gm (power supply)

Spectrum Probe analysing transmitter RF output.for harmonics



The Type 107 Spectrum Probe allows any standard oscilloscope to be used as a 100MHz spectrum analyser; the vertical deflection indicates amplitude (on a logarithmic scale) while the horizontal scale gives a (linear) indication of frequency. Mike Tooley reviewed the Laplace Instruments Spectrum Probe in the November 90 issue of Electronics World+Wireless World. This is what he had to say: "***The ability to display signals in the frequency domain on a conventional low-cost oscilloscope should not be underestimated. Indeed, it should be stressed that the Spectrum Probe can display signals at 100MHz far outside the bandwidth of, for example, a 10MHz oscilloscope.***"

Our magazine is pleased to be able to offer the Spectrum Probe to its readers for just £295, £45 off the normal price. To order yours, simply fill in the coupon below and return to Lindsey Gardner, Room L333, Quadrant House, The Quadrant, Sutton, Surrey.SM2 5AS. Alternatively phone in your order on 081-661 3614 (mornings only).

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AUTOMOTIVE AUTOMATION

PART 2

The car makers have always been able to produce a product which could move as fast as their marketing departments wanted. Electronics has given the motor industry something else to sell on. By Tom Woodford.

Vehicle management and "driveablility" is the growth area for electronic systems. Features and facilities which were not cost-effectively achievable even as options by other means are becoming the standard.

Brakes. The most significant development must be anti-lock brakes, but traction control, adaptive suspension, four-wheel steering, climate control and other secondary safety systems are all now available. Secondary safety features are those which make the car easier to drive or save the driver from himself. It is arguable that ABS leads to more dangerous driving, as it enhances the belief that one is invincible.

ABS operates by sensing the onset of wheel locking with a rotation sensor, usually a reluctance probe and toothed wheel. The control system momentarily releases the brake at the offending wheel by triggering an electro-hydraulic actuator to "fight" the driver with opposing hydraulic pressure. This gives a disconcerting "pulsing" through the brake pedal which, in the best electronic tradition of dressing up a bug to look like a feature, is claimed to give the driver positive indication that the system is working. Most systems are three-channel, with separate speed sensors on each wheel, but with the rear wheels sharing an "unbraking" valve.

Knowledgeable road testers in the motoring press claim that a skilled driver can always outperform an ABS system in back-to-back tests, but we are not all skilled and it is the unexpected situation when tired at the end of a long day that kills you; similar arguments have applied for years to automatic gearboxes.

Ford pioneered ABS as a standard fitment to all current Granadas, using the Alfred Teves system. Bosch and Honda offer similar systems, which are becoming standard equipment on most upmarket executive cars.

Traction control is an interesting integrated-system concept. The ABS wheel rotation sensors are used to detect the onset of wheelspin under hard acceleration, the control system then applying the brakes and/or reducing engine power to maintain directional stability.

This concept was taken to extreme on the Porsche 959 supercar, where the electronic systems also operated sophisticated clutches to direct power to the wheels with most grip at all times. A heuristic system, the processor could "learn" the operating characteristics of the car to differentiate between tyre slip due to pressure differences and genuine wheelspin. This system is not quite smart enough, however, as the driver must operate a switch to tell the controller if the road surface is ice, snow or loose gravel.

Active suspension. Seen on Lotus and Williams Formula 1 cars, fully active suspension was also demonstrated by GKN in a fully-hydraulic system some twenty years ago. The car's conventional springs and suspension are replaced with fast-acting hydraulic rams. A whole range of accelerometers monitor vehicle movement in three planes on two axes, further sensors monitoring steering angle and vertical loads at each wheel. The processor then computes the required position for each wheel and commands the suspension rams to move accordingly. Processing and electro-hydraulic demands are quite staggering, needing a 32-bit processor running at 20MHz.

Advantages in adhesion and stability are equally dramatic: the car can be tailored to provide any desired handling characteristic — it can even be programmed to lean into (instead of away from) bends. Cost will keep such systems in the "of interest" league, unless there is a sudden world shortage of steel springs. It is significant that none of the F1 teams now use active suspension. Nevertheless, as a demonstration of what is now achievable by electronically controlled mechanical systems in consumer applications this is a phenomenal development.

Semi-active suspension is merely interesting by comparison. Less sophisticated, but still numerous sensors monitor vehicle movement and driver demand. The system processor triggers fast-acting valves on otherwise conventional spring/damper units to increase suspension damping from "soft" to "stiff" (or "sport") when required. Transition is achieved in less than 10ms and such systems offer improved ride comfort without the penalty of roll and float associated with soft suspension. Manual override is usually provided for the keen driver to select the firm setting when required. The systems switch automatically from soft to firm at predetermined road speeds to maintain vehicle stability. Extensions to this principle use Boge self-levelling spring/damper units to lower ride height by 10-20mm at high speed to improve aerodynamic stability.

'The imaginative engineer can add all sorts of nice touches. On the Ford Granada, the rear screen wiper is automatically started if reverse gear is selected when the front wipers are on. The 7-Series BMW will switch the wipers to intermittent when the vehicle is stationary to avoid nasty squeaking noises'

Hydractive suspension is Citroen's proprietary semi-active system and goes one stage further than demand-adjustable damping by using an additional, electrically switchable hydro-pneumatic spring. The system not only increases damping but also increases spring rate when needed. This offers further improved high-speed cornering stability.

Climate control may not seem as glamorous as ABS or ETC, but is still a significant secondary safety feature, again becoming integrated with other in-car systems; for example, to direct all air to the windscreen until the engine is warm, to avoid cold feet. More importantly, it signals the engine management system as the air-conditioning compressor is engaged, so that the idle speed can be increased to compensate for the sudden engine load. Much research has been conducted to determine the correct differential temperatures to foot, chest and face level to prevent drowsiness and some systems contain very sophisticated processors to ensure that these differentials are maintained.

Four-wheel steering is verging on the "gimmick" category, although it is claimed to offer dramatic stability benefits in high-speed lane changing or swerving manoeuvres. In this case, the rear wheels are turned in the same direction as the front ones; low-speed manoeuvres (parking) are enhanced by turning the rear wheels in the opposite direction. Mitsubishi, among others, have demonstrated complex processor-controlled systems operating hydraulic rams to steer the rear wheels. Numerous sensors are used for the system to determine which way to steer in any set of circumstances. Since Honda have now introduced a very simple, purely mechanical system, it is unlikely that the electronic systems will have a long production run.

Bus-bar systems are, perhaps, the most significant sensible application of simple electronics in a vehicle environment. The wiring loom of a modern car, in particular up-market models laden with options, contains around 25-35kg of copper. An obvious solution is already used in modern aircraft, in which a bus-bar feeds power to individual ancillaries, which are attached to the bus where required and contain a data decoder with a unique address code. The controlling switch or processor is also attached to the bus where required, and sends the "on" or "off" instruction preceded by the identity code of the addressed device.

Such a data multiplexed system has been shown to save some 30%-40% of copper weight alone, and at today's metal prices is highly cost-effective. Significant further benefits are available in production, for adding options to order as the car is assembled. Similarly, the addition of aftermarket options is greatly simplified. It also offers some potential for the owner to "customise" the control layout to personal preferences.

Although suitable multiplex communications protocols and hardware already exist, such as the I2C bus, the hostile vehicle environment precludes consumer ICs. Conversely, the 1553 avionics bus is somewhat of an overkill. Cars with limited bus systems are already on the market and the development of totally integrated vehicle control will depend on the extension of multiplex control to the whole car. To meet the CARB monitoring requirements will otherwise be impossible.

Instruments.

Most dashboards have sported an "electronic" tachometer since the late 1950s, with a capacitor-diode network to convert the frequency of pulses from the contact-breaker to a voltage for meter deflection.

Most manufacturers have flirted with "electronic" displays and many have discovered that, in Europe at least, drivers prefer traditional, round, analogue instruments.. One wonders if the new monitoring systems will eliminate all but the speedometer from dashboards of the late 1990s.

PCB sub-assemblies have been used for instrument panels for some years and the traditional Bowden-cable speedometer and odometer drive has been replaced by a toothed-wheel magnetic transducer, "electronic" meter and electromechanical pulse counter. The latest Rolls-Royces have made the radical break with tradition by using a fluorescent display to indicate gear selector position.

Crude monitoring systems, in particular for bulb failure, use discrete logic or a dedicated consumer microprocessor to detect breaks in circuit continuity.

Primary safety systems are still some way in the future. It is also doubtful if they will gain user acceptance without legislative compulsion.

Servicing and reliability

Most of the current engine management systems have diagnostic sockets, which can be attached to an analysing computer by the servicing dealer to check vehicle performance.

Citroen produced an example of the "ultimate safe car". It was made of glass and had a nine-inch spike sticking out of the middle of the steering wheel. The theory was that no-one would risk an accident in such a vehicle

BMW have pioneered the "intelligent odometer", which offers the driver a led bar-graph to indicate when the next service is due. This system monitors the driving style, car duty cycle and other wear-relevant parameters to provide the user with genuinely useful information. A secondary benefit, for the dealers, is that the customer must visit a BMW service centre to have the lights re-set. This helps to maintain brand loyalty.

In theory the mid-1990s car, equipped with the full CARB compulsory monitoring system, could detect a fault, order its own spare parts using a data link over the car's cellphone, then telephone to book a service appointment with the dealer, having first checked with the owner's diary for a free date.

Entertainment, information and navigation

The very first in-car electronics were pre-war valve radios, which used vibrators to generate the HT (that will not mean the same to younger readers) and occupied most of the passenger's foot-well, where they also served as a heater. Now, they accept a cartridge of CDs, and occupy most of the boot instead.

In-car entertainment is well known to most car owners and needs little further comment. Most line-fit ICE systems have acceptable performance, only let down by playing through six or ten speakers, none of which costs more than 40p.

The Philips/Renault ICE controls, with full remote operation available from a column stalk, should be made compulsory as a safety contribution long before monitors to detect fluorocarbon leaks from the air-conditioner.

Much has been made of the new RDS system in the UK. While invaluable to motorists for its automatic re-tuning capabilities, the traffic information service facility will become infuriating for motorway and trunk route users. Automatically re-tuning the radio to local stations broadcasting traffic information, it will be really useful to hear about major local congestion problems that one is by-passing at 70mph. The French system, of low power transmitters on a common network, offers only Autoroute-related information on a single national frequency. This is close to the original BBC CarFax FM-capture concept, which would have been highly successful had it not been killed off by set-makers' vested interests in rival systems.

Navigation systems, such as the Blaupunkt Travel Pilot, are now becoming commercially available. Offering a moving-map display, they will guide the driver to a destination previously entered. Linked to police or motoring organisation traffic information services, such systems offer the possibility of detours to avoid congestion or the M25. Basically inertial guidance computers using maps stored on CD ROM, such systems may be overtaken by more recent developments using the American, satellite-based global positioning system (GPS).

Toys from the marketing department

How useful you find a trip computer depends on how often you get bored on the M25.

Some trip computers are obviously included to fill up a hole in the dash. The device provided on a Rover 800 does clever things like pick up the sum of fuel injected from the engine management system and use it to display, very accurately, how much fuel you have used since you last remembered to reset it. This information is virtually useless unless you know the exact capacity of the fuel tank and have a calculator with you, since the answer you want is how much fuel is left, or (better still) how many miles to empty. Similarly, many of these devices offer an "arrival time" function. If the ETA were calculated on average journey speed this would be helpful,but calculating from instantaneous current speed gives a silly answer, with an ETA in the year 2000 every time you stop at traffic lights.

Some convenience functions are much more useful. The PLIP remote infra-red central locking system is helpful in the dark or when the keyholes have frozen over. If you use your universal "learning" domestic remote control to store the key's IR stream you can unlock the doors from 200 yards away. This French system uses dedicated ICs hard-coded with a digital sequence. In theory vastly more codes can be accommodated than is achievable with conventional metal keys.

Once he has access to control signals from other vehicle systems, the imaginative engineer can add all sorts of nice touches. On the Ford Granada, the rear screen wiper is automatically started if reverse gear is selected when the front wipers are on. The 7-Series BMW will switch the wipers to intermittent when the vehicle is stationary to avoid nasty squeaking noises; the intermittent wipe rate is also speed dependent and increases as the car goes faster. When reverse is selected the passenger's door mirror is dipped down a few degrees so the driver can see the kerb when parking.

Many executive saloons have an electronic timed delay on the interior lights so that they stay on after the car is entered and are cancelled as soon as the engine is started. The Rover 400 goes one better and fades the lights out gently, proving that the miracle of electronics has indeed had a hand.

The real future

While the marketing men find really useful things like interior light faders for the electronics engineers to design, the advances made in engine management appear slow and ponderous by comparison. As yet, no true closed-loop or feedback control techniques are used. Current systems function only as extremely sophisticated open-loop set-point generators, based on a small sample transposed to all units in a production run. Sensors initiate corrective action only when operating parameters are obviously exceeded, such as knocking or detonation.

What is needed for the future is a different approach, measuring what is actually happening inside the engine, instead of only external symptoms. This will require the further development of existing sensors. One approach is to measure the cylinder pressure during the combustion cycle, this, among many other things, being a direct measure of the combustion process. This concept was explored by Christopher Clarke and Peter Wibberley of the leading independent consultancy in this field, Ricardos. They evolved a complex algorithm to predict several critical performance criteria from direct cylinder pressure readings taken from an engine over the relevant part of a cycle.

Figure 1 shows example cylinder-pressure diagrams measured directly on a Ricardo test engine. Predicted results were made for air-fuel ratio, EGR, unburnt hydrocarbons, CO, NO_x and CO_2 and plotted against measured data. **Figure 2** shows the air-fuel ratio result, and **Fig.3** the CO_2 plot as examples. The correlations are remarkably close, but exhibit significant "noise" or scatter, possibly due to errors in the prediction algorithms and to cycle-to-cycle in the various measured parameters. Nevertheless this is an ideal DSP application. Although the cylinder pressure sensors would be generating data at a very high rate, this would be well within the capability of current digital signal processors.

Ricardos' proposed outline of a closed-loop EMS using these techniques is shown in **Fig.4.** A system along these lines is not currently commercially feasible, since the necessary pressure sensors are only available in prototype quantities and prices. Further research needs to prove the validity of the predictive algorithms under wider operating conditions, but the overall technique looks very promising as a significant step towards the more stringent EMS requirements of the mid 1990s. One further problem is the physical space needed to locate the new sensors with adequate access to the combustion chambers, since modern cylinder heads are totally devoted to multiple valves and spark plug; if there is adequate need a way will doubtless be found. It may be significant that at least one major engine manufacturer has already incorporated a provision for cylinder pressure sensing in their next-generation engine designs.

References

1. Wibberley, P. and Clark, C.A., Ricardo Consulting Engineers, Ltd. "An investigation of cylinder pressure as feedback for control of internal combustion engines." *SAE* 890396 .

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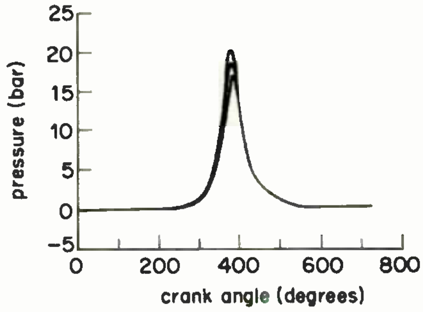


Fig. 1. Measurement of cylinder pressure during combustion cycle for a typical

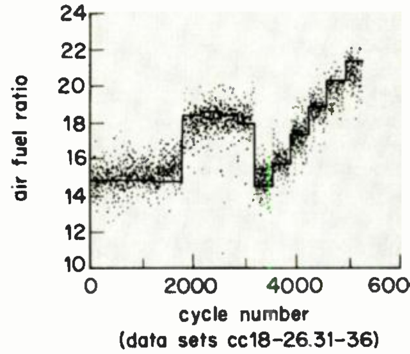


Fig. 2.Electronics isn't perfect: measured variations between predicted and measured air/fuel ratios in a Ricardo

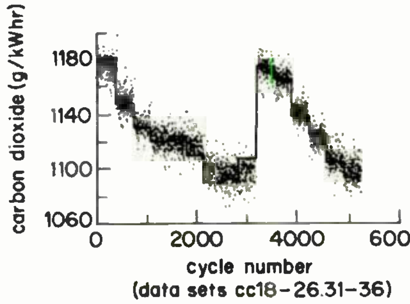


Fig. 3. Differences between predicted CO_2 exhaust gas levels in a research engine

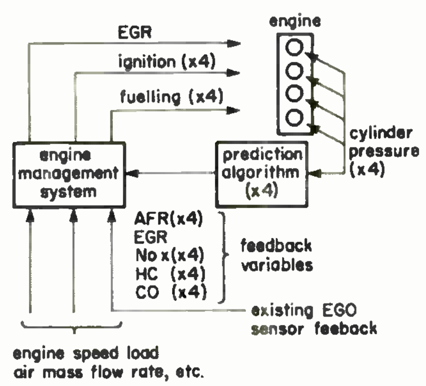


Fig. 4.Ricardo engine management system based DSP using the results of

Back to the future

I read with interest the article on Benjamin Franklin in your February issue (Pioneers: Benjamin Franklin — printer, postmaster, scientist and statesman *EW + WW* pp. 158-160). But I felt that his interest in the future was an omission. In particular I quote from a letter[1] he wrote to a friend James Duborg, in April 1773:

"I wish it were possible, [reference experiments in which he revived flies drowned in Madeira wine] to invent a method of embalming drowned persons, in such a manner that they might be recalled to life at any period, however distant; for having a very ardent desire to see and observe the state of America a hundred years hence, I should prefer to an ordinary death, being immersed with a few friends in a cask of Madeira, until that time, then to be recalled to life by the solar warmth of that country!".

Although somewhat fanciful, Franklin's idea had a basis in the science of his time. The 18th century microscopist van Leeuwenhock observed that if he dried the microscopic animals rotifers they could be revived by adding water[2].

Franklin believed that extending life-span would benefit individuals and the species — in distinct opposition to opinion of his time.

The Epicurians, for example, thought that only a limited number of pleasurable experiences were possible. In the Bible there are accounts of people routinely living thousands of years in early periods, and this gave rise to the popular belief that things were always better in the past.

However unless any of readers of *EW + WW* who are interested in alternative physics can come up with a mechanical time machine, Franklin's wish remains unfulfilled, except that is for the actions of a small group[4] of scientific renegades, the cryonicists.

They freeze people at the point of death in liquid nitrogen, after carefully preparing the bodies with cryoprotectants. Reasoning is that it will be possible, by nanotechnology or otherwise, for future science to repair the bodies of ageing damage — the cause of death — freezing damage, and restore them to a life of indefinite duration.

John de Rivaz
Truro

References
1. Gerald J Gruman: History of ideas about the propagation of life. *Trans Am Phil Soc*, Philadelphia, Dec 1966, vol 56, part 9 p.74.
2. Gruman, *op cit*, p.84
3. Gruman, *op cit*, p.84
4. Alcor UK Ltd, Unit 18, Potts Marsh Industrial Estate, Eastbourne Road, Westham Sussex.

Keep worrying

I am writing in response to GS Brown's letter which appeared in your September 1990 edition (Facts not pax p.817).

His comments were offensively patronising and I am amazed that anyone of professional competence could openly advocate that worrying about the effects of technology should be left to social workers. This is tantamount to championing abdication of responsibility for the negative aspects of technology.

Only human concern at all levels provides the necessary checks and balances to application of science in our imperfect world, and a restraint on an elitist technocracy. Wherever there is any controversy about technology, wide ranging and healthy debate should be encouraged and how better to do this than to highlight the issue by publication of the facts in reputable journals of high calibre such as *EW + WW*.

Your recent series of articles on EMR and non-ionising radiation has been brought to the attention of Justice Sir Harry Gibbs who is conducting the power line enquiry in New South Wales.

The information they contained will undoubtedly be taken into consideration during formulation of policy which will affect future generations of Australians. The articles have also reached interested medical specialists.

Many of your readers look forward to being kept informed about contentious issues, so keep up the good work.

Peter Harding
NSW
Australia

Unix supported

I was most interested to read your Unix feature in February 1991 issue *EW + WW* (Nothing but Unix, Dos/Unix — the price of change, Open a window on Dos and let in new life, pp.106-114).

While the articles were fairly comprehensive, I felt that they nonetheless perpetuated a few myths about Unix. Having used a small SCO Xenix system in a small business for the past couple of years, I would like to take issue with the following points:

You suggest that Unix software is expensive; well, yes, but so is dos software for networks, often more expensive on a per-user costing, and prices are falling.

Hardware to run Unix is expensive: not necessarily, a system for, say four to 16 users is cheaper to implement with a 386-based machine and character terminals than with a dos network. Unix is large and unfriendly: yes, but dos is equally unfriendly, which is why most users have a graphical or text-based menuing system. Creating a text-based set of menus in Unix is a simple matter, which the supplier should implement, so that the user need never see the command line. A Unix system needs the constant attention of qualified and therefore expensive personnel: indeed, familiarity with computers and an appreciation of the importance of back-ups and other housekeeping tasks is vital, which is why our receptionist performs these functions perfectly well and very reliably. The service contract should cope with any other problems.

I could go on, but to sum up, any small business moving from a single dos machine would do well to look at a Unix/Xenix system. It is cost-effective to install, the service contract can be cheaper, and expansion is easy and cheap.

Many dos programs are also available for 386-based Unix/Xenix systems, at prices comparable to their dos networked counterparts.

Stephen Biggerstaff
Advertech Communications Ltd
London

Duck grouse

Your correspondent D Austin of Birmingham was quite wrong to assume in February issue *EW + WW* that gyroscopic inertial thrust machines are a "dead duck" (Letters, Quack technology p.150).

He referred to the television documentary *The Man Who Wants to Change The World* in which he says that such a device built by Scottish engineer Sandy Kidd was claimed to work.

In my recently published book "Beyond 2001", tracing the history of Kidd's invention, there is a detailed description given of how this device was proved to work during tests conducted at specialist laboratories in Melbourne three years ago.

Kidd's prototype, encased in a wooden box suspended by a Kevlar Cord from an overhead beam, registered a positive result in every one of twenty consecutive runs, the force measurement ranging from just under half-an-ounce right up to four ounces.

No one has yet been able to prove how the machine works: but work it does.

Talk of "dead ducks" therefore is greatly exaggerated.

Ron Thompson
Author "Beyond 2001"
Dundee
Scotland

Testing disharmony

In his article on triple-tone audio amplifier testing (*EW +WW* Feb. 91, Trial by three tones), Ivor Brown appears to be unaware of the work of Paul Miller in this area, as published in sundry amplifier reviews over the last couple of years (principally in *Hi-Fi News* and *Hi-Fi Choice*).

Although the frequencies and relative amplitudes used are different, Miller's technique is based on the same premise: that complex intermodulation products can reveal more about an amplifier than conventional, "static", single-tone tests.

Miller, in fact, has taken the principle a stage further, by using one constant tone and two sweep tones, sweeping at different rates. The resulting spectrum is plotted as a "three-dimensional" graph, showing up quite unequivocally the harmonic and intermodulation products generated in a DC-100kHz bandwidth, with remarkable clarity.

Even so, these techniques still use signals which are at best "semi-static", and the use of fully random, or pseudo-random, tones would be an interesting further development.

On the other hand, single-tone tests are capable of showing up quite a lot of detail provided they are made sensitive enough, and, particularly, are conducted at different frequencies and power levels.

High harmonic distortion — say, above tenth order — seems to have very strong effects on perceived sound quality, and I have found it necessary on occasion to measure down below -100dB to find anything "wrong" with amplifiers which, on blind auditioning, show a subtle sonic signature. This is perhaps not quite as far-fetched as it may sound.

but I would be the first to admit that it is strange we can hear such small imperfections at the end of what is often a long and complex recording chain.

In the same issue, you discuss some research on the phenomenon of absolute pitch (Singing the blues — or reds, or greens or...).

I have absolute pitch, and have always found it most peculiar that others do not. There seems to be more to it than memory of what a note sounds like, for I can also sing or whistle a note on pitch (or at least very close) without preparation, implying that I remember physically what the note feels like.

So why can singers not do this? The human voice has certain characteristics which are remarkably pitch-constant. For example I frequently accompany a singer who has certain vocal problems, always at the same frequency, and whose speaking voice is constant in its "tuning" (both true of most singers), yet she does not have absolute pitch and will often guess a note in error by up to a major third (26%).

On the other hand, when I commented on one occasion that a certain recording sounded a little flat, she replied that it sounded correct to her — and was proved right!

Richard Black
London

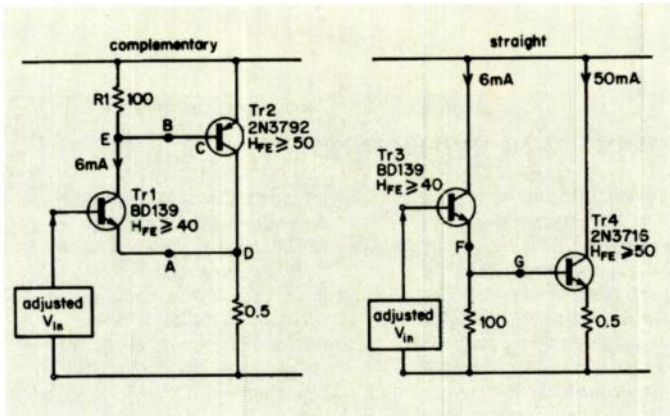
Amplifying diode

The output stage in a class B audio amplifier consists of two halves, one for each direction of current. Each half is normally a Darlington structure, either complementary or straight, as shown in **Fig. 1.**

In his November 1989 article (*EW + WW* Solid-state audio power pp.1042-1048) John Linsley Hood said that the complementary arrangement has better thermal stability.

But Les Sage disagrees. In his March 1990 letter (Audio power pp.236-237) he examines first the straight case, and notes that the electrical effect of a 1°C rise at either junction can be modelled by inserting a 2mV generator at F or at G. This produces an extra 2mV across the 0.5Ω resistor, thus fixing the increase in the quiescent current through that resistor.

Then he observes the same resistor in the complementary circuit, and concludes that a 2mV generator at A will yield 2mV across



the 0.5Ω resistor, to produce the same increase in quiescent current as before.

Thermal stability is the same for both circuits!

In his January 1991 letter (Audio amplifier bias current p.53) JN Ellis points out a slip: 2mV generators inserted at F and at G will produce twice the voltage of the single generator at A. These voltages are handed on to the 0.5Ω resistor. So 1°C rise produces 8mA increase in quiescent current in the straight case but only 4mA in the complementary case, which is therefore the better arrangement.

Analysing thermal effects in Tr_2 is harder, because of the feedback involved.

Neither writer produces figures for Tr_2, thus invalidating any comparisons of the two circuits. Further, both repeatedly assume that a 2mV generator inserted at, say, G will devote its entire 2mV to increasing the current through the 0.5Ω resistor: no part of the 2V is needed to increase current in the transistors. With sub-ohmic emitter resistors, this is an invalid procedure.

To summarise, the correspondents have assumed V_{BE} remains constant as current changes. In fact the change in V_{BE} may be accurately modelled by assuming that V_{BE} does not change, but that there is in series with the emitter a model resistor of value 25/IΩ, where I is emitter current in mA.

For example, Tr_4 has a model resistor of 0.5Ω, in series with the 0.5Ω shown. It is now clear that 1°C rise in the straight case produces 4mV total at F and G, but only 2 mV of this falls across the real 0.5Ω resistor, to yield an increase of just 4mA in the quiescent current.

Suppose V_{in} increases enough to augment Tr_1 V by 1mV: collector current will increase by 0.25mA (the model resistor is 4Ω). 4/5 of this comes from Tr_2 base (from B Tr_2 model resistance is H_{FE} x 0.5Ω).

Thus 10mA flows down to D raising it by 5mV: V_{in} was 6mV.

Since the generator at A may be considered instead as part of V_{in} it now follows that nearly all the 2mV at A appears across the 0.5Ω resistor, to give an increase of 4mA in quiescent current.

The methods that follow show that B has little effect. But compare the previous paragraph: the two circuits are back once more on level pegging.

In practice V_{in} is supplied by an *amplified diode* (pot with its three leads connected to a transistor). This largely eliminates the gradual thermal effects of the above discussion, if it is in contact with the output transistors.

But the system is still vulnerable to rapid increases in amplifier output.

Suppose that the fully loaded amplifier is suddenly made to deliver a steady square wave of amplitude one quarter of the total supply voltage (the worst possible case). This might cause the power transistor junctions to heat 100°C in a few seconds, with much less effect on the other transistors involved.

Dynamic (time-related) behaviour of this kind is much more likely to trigger runaway than the gradual drifting discussed above. In the straight case, 100°C rise produces in effect a 200mV generator at G.

Noting the 0.5Ω model resistor in series with Tr_4 emitter, just 100mV falls on the real 0.5Ω resistor. The bias current has increased by 200mA — only an approximate answer because change in I is no longer small. An accurate method predicts 300mA increase).

The complementary circuit fares much better, when a 200mV generator is dropped in at B.

To see what happens, work from a less enmeshed variable. Suppose that generator B has lowered C by 1mV. Well, the model resistor for Tr_2 is 0.5Ω, so its emitter current will increase by 2mA: this raises D by 1mV. That will send 0.25mA back up through Tr_1 (its model resistor is 4Ω). This 0.25mA is joined at E by $2mA/H_{FE}$ = 0.04mA from Tr_2 base. 0.29mA flows up through the 100Ω, raising E by 29mV. So B was a 30mV generator.

But our real B is 200mV, and as all goes in proportion the extra bias current through the 0.5Ω is not 2mA but 200/30 x 2 = 13mA.

Straight Darlington produced 300mA, so complementary does 23 times better. Game, set and match to Linsley Hood!

This discussion handles only one of the factors that determine thermal stability. But a general conclusion can already be drawn. Any other system would be of real interest if it threw out the amplified diode, together with the dangerous thermal balancing act that it supports.

Such a system was proposed in my October article (*EW + WW* 1990 Reducing crossover distortion pp.879-882) and Mr Ellis sets out to criticise it. But he fails to offer any criticism.

Instead he relies on Reg Williamson's view that the subject of crossover distortion is long since closed. It is true that in his November 1988 letter (The subjectivist manifesto pp.1067) Mr Williamson did refer to his June 1969 article, and he came within a whisker of saying that it had covered comprehensively the matter of crossover distortion.

By courtesy of Mr Robson of Stevenage Marconi I have been able to examine this 21 year old *WW* article, and it makes just one point on crossover distortion: fully complementary output stages would eliminate the odd harmonics that cause most of the unpleasantness.

Magisterial and indeed prescient, but scarcely comprehensive, and certainly no criticism of the October article.

In his December letter (*EW + WW* 1990 Crossover distortion pp.1044) Erik Margan of Ljubljana does comment on my October article.

He observes that measuring spikes is an insufficent criterion for crossover distortion. The temporary switch-off they cause of higher frequencies is most important. But can this happen in the proposed system, where the spikes only last 1µs, and are not 167 times (as I wrote) but 333 times less serious than those he has tested?

Michael McLoughlin
Haberdashers' Aske's School

Unsound model

I read with interest Michael McLoughlin's article on crossover distortion in the October issue (*EW + WW* Reducing crossover distortion pp.879-882).

The article is informative and thought-provoking as far as it goes. But it has some limitations when applied to modern power amplifier topologies.

I do not think anyone would use a circuit as simple as that presented except for amplifiers of 1 or 2W capability in non-critical applications, where it might be argued that cross-over distortion is not a significant consideration.

The major problem as I see it is that Mr McLoughlin's circuit model is not sufficiently representative of modern amplifiers in two main areas. First, nearly all modern audio power amps of average to high performance use differential pairs in their first stages. The differential (or long tailed) pair provides greater signal handling capability, linearity and common mode rejection compared to a single transistor, at the expense of some gain.

Second, Mr McLoughlin's model uses high gain small signal transistors in the output stage, which are quite different from the large and relatively slow power transistors normally found in power amps, and quite different also from power Mosfets.

Use of differential pairs is perhaps the most important with regard to Mr McLoughlin's conclusions.

For differential (long tailed) pairs the impedance seen from the emitter of either input transistor is pretty much just the intrinsic emitter resistance (r_e) of the other transistor, and the first stage gain has little or nothing to do with the impedance of the feedback circuit.

Under these circumstances reducing the amplifier's closed loop gain to unity would not provide as much benefit as Mr McLoughlin would have us think. The subsequent increase in feedback should reduce all distortions, as we expect feedback to do, but reducing the amp's gain to unity might have some rather undesirable effects.

For example a 50W amp would be expected to deliver just over 28V to an 8Ω load. If it were a non-inverting amplifier with a gain of unity then the input voltage would have to be 28V as well, requiring an input circuit of large signal handling capability and much higher common mode rejection.

Another point to consider is the power supply voltage. The biasing requirements of most input stages are such that they cannot accommodate both supply voltages in their input (or output) range.

In fact most power amplifiers cannot accommodate either supply rail voltage at their inputs. To maintain a reasonable efficiency, supply voltages are kept as low as possible while still delivering sufficient voltage to obtain the required output power.

However if the amplifier's input is required to handle full output voltage of the amplifier, as it would if the amp had only unity closed loop gain, then larger supply voltages would be required for the input stage.

This implies either two sets of supply voltages, or larger supply voltages for the whole amplifier which means a less efficient amplifier and output transistors with higher power ratings and bigger heatsinks — all adding considerably to cost of the final unit.

It is revealing that all of Mr McLoughlin's measurements appear to have been done at an output level of 2V peak-to-peak with a total supply voltage of 9V, and very little attention has been paid to the full power capabilities of his circuit.

In fact if the DC voltage at point F is only 2.7V (as stated in his Fig) then we could not expect a maximum output voltage swing of more than approximately 2V peak (4V peak-to-peak). This is very inefficient use of the available supply and could not be tolerated in a modern high powered amplifier.

Another point that Mr McLoughlin has largely ignored is the different frequency compensation required for a unity gain amplifier and its effect on slew rate. Very few amplifiers can provide the same slew rate at unity gain that they might at higher gains, say 30dB.

Inadequate slew rate is probably the dominant cause of TID. Slew rate is an important parameter that must be considered when designing a power amp and, for a given design, lower gain usually necessitates lower slew rate unless other design requirements are sacrificed. It is pointless to trade one type of distortion for another when an alternative design reduces both.

As for the output transistors, Mr McLoughlin has not allowed for the much slower response of power transistors compared to the small signal transistors he has used in his model.

When configured as an emitter follower a bipolar transistor has a 3dB bandwidth approximately equal to its f_T. For a BC 109 this might be between 100MHz and 300MHz, and for a BC 327 it might be 50MHz to 150MHz.

It is unlikely that any bipolar power transistor could manage anything more than 100MHz, and Mr McLoughlin's circuit is less relevant to power Mosfets. This simple fact could largely account for the apparently poor crossover performance of the amplifiers tested by Vandekooy and Lipshitz, and Margam when compared to McLoughlin's simple little amplifier.

Also real life amps often use Darlingtons for the output transistors and this will contribute to the size of the crossover spikes.

Mr McLoughlin recommends use of a current source in the collector circuit of the second stage of his amplifier, to reduce the effects of crossover distortion.

Most modern power amplifier designs already use similar circuits in that position and so Mr McLoughlin's suggestion is a bit pointless. Many amplifiers use a push pull arrangement which is usually more linear and can provide more gain from the stage.

I feel that the major shortcoming of Mr McLoughlin's article lies with his failure to relate the work he has done with his amplifier to modern amplifier topologies, and there are important differences between his amplifier and modern class B power amps.

Based on this I find his conclusions are dubious, in particular his claim "that the amplified diode has had its day".

In my experience, when crossover spikes appear in an amplifier no amount of feedback will remove them, and the only acceptable course of action is to avoid them in the first place.

I cannot see that Mr McLoughlin has presented an acceptable alternative to the amplified diode, except for simple amplifiers of about 1W output power. Having said that I must say that I did find the article interesting and thought-provoking. I think that reconnecting the compensation capacitor (to the output terminal) looks like a very sensible idea. Perhaps further investigation of the subject might be in order with a circuit more representative of modern Class B amplifiers.

Phil Denniss
University of Sydney Australia

Editorial survey: use the information card to evaluate this article. Item Q

Truth and gyroscopes

From reading his description in February letters (Quack technology), it is clear to me that D Austin did *not* reproduce the experiment demonstrated by Raymond Baxter on the BBC *Tomorrow's World* programme. Support arms for the top were allowed to hang vertically and the centre of the support pin was assigned to be the reference point on the machine. A stop was arranged to halt the support arms moving beyond the vertical to, say, the right.

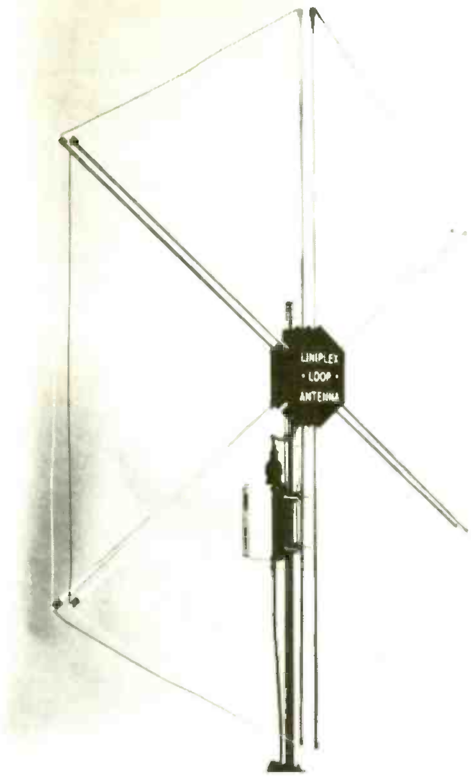
In operation, the top moved to the left, the frame to the left and, at the end of the traverse swing, the supports were again touching the stop.

The top now behaved as a simple Newtonian pendulum and swung back across the machine, regaining its start attitude. A smaller pulse to the left followed.

By examining the bench marks, it was clear that the machine had translated to the left without rearward reaction. In effect, the stop was a mechanical rectifier which prevented precession to the right.

On the fifth of May, 1972, I showed Professor Laithwaite a 10lb machine, the bearing losses of which were sustained by 10W of electricity. The length of the first pulse was about 8in, which took the device completely beyond its original boundaries.
I have an affidavit to that effect.

Alex Jones
Channel Islands



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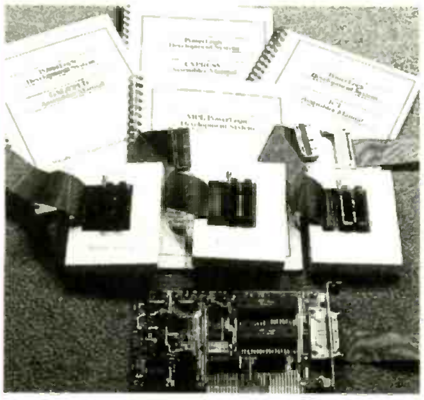

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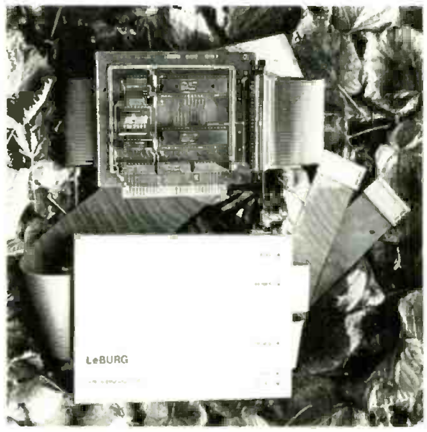

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FM RADIO: PLAYING A BETTER TUNE

John Linsley Hood continues his short series on FM receiver design, looking at the way in which component development has influenced technique

In the first part of this article I looked at the reasons for the growth of VHF radio broadcast systems in which the carrier was modulated in frequency, rather than in amplitude, and at the evolution of receiver designs for FM transmissions.

Although workable and offered as normal commercial products, these early FM radios were not entirely without residual problems. Most annoying were the very high levels of inter-station noise and the short-term thermal drift of the tuning setting, due to the heat generated by the receiver valves.

I felt that a suitable point to end this part of the article was in 1960, when the first transistor-operated designs began to appear, since these, being cool running, offered at least the possibility of avoiding the second of these problems.

Stability of tuning

From the inception of FM broadcasting on the VHF bands, it was obvious, particularly to those hostile to the adoption of the system in the first place, that there would be a practical problem in obtaining adequate stability of tuning. This would arise because a 0.1% drift in the resonant frequency of a 1MHz tuned circuit, which would be relatively unimportant in the 8-10kHz pass-band of a typical medium-wave AM receiver, would be unacceptable in an FM discriminator system intended to operate on a ±75kHz carrier deviation.

Because of this need to operate at relatively high frequencies, most of the valve-operated FM tuner designs of the time suffered from some drift in tuning frequency, though efforts were made to minimise this irritating problem by the sensible choice of components, circuit structure and layout.

In retrospect, it is surprising that so few circuits of the time used the mean direct-voltage output of the FM demodulator circuit, which is a function both of the extent and the direction of mis-tuning of an input signal, as a basis for some form of automatic frequency control. Miller capacitance circuits of the kind shown in **Fig. 1** had been known and used for many years in other applications and would have allowed a useful degree of frequency control in the oscillator circuit of an FM superhet radio. It is now, of course, an easy matter to arrange this type of control by the use of a Varicap diode connected in parallel with the oscillator tuned circuit.

The use of AFC is not, in itself, a complete answer to the problem of tuning drift, unless this is fairly small anyway. In the presence of uncorrected drift, the receiver AFC circuitry may pull it into tune on an adjacent signal channel at switch-on, rather than the one to which it had been tuned when switched off.

Inter-station noise

Even after the widespread adoption of cool-running, solid-state circuitry had made short-term tuning drift a relatively minor problem, there remained the problem of off-station noise. This was particularly conspicuous in high-gain systems using amplitude-limiter circuitry, since the thermal noise of the input stage would be amplified to become a wide-band FM signal at an effective 100% modulation level.

From the point of view of the amateur constructor a simple, if rather expensive, answer to the problems of both inter-station noise and drift was to use a crystal-controlled oscillator, its operating frequencies being appropriate to the three BBC channels broadcast in any given area, so that the radio could be switched from one channel to another without passing through the noisy inter-station region.

This was a widely adopted approach in FM receiver systems using pulse-counting demodulators[1,2,3], for which stability of the IF output frequency was essential.

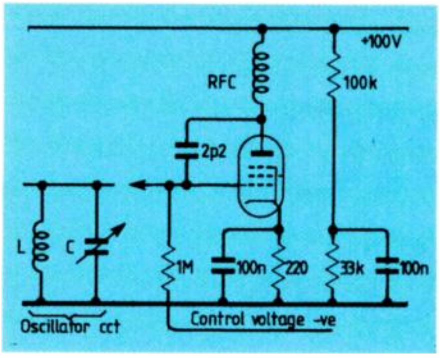

Fig.1. Vari-mu pentode used as Miller-capacitance stage for AFC purposes.

However, quite apart from considerations of cost, the use of crystal-controlled oscillators lacked appeal to the commercial manufacturer making products for use country-wide, although in 1961 STC offered a range of three-crystal packages mounted in a B9G-type glass envelope to allow a change of frequencies.

Various techniques were employed for inter-station noise muting in continuously tuned receivers, but the most common method was to derive a voltage proportional to signal strength, which could then be used to operate an audio switching circuit, as in **Fig. 2.** An ingenious alternative system, based on the detection of high frequency components in the demodulated output and used to operate a fet switch, was shown by Hinch[4].

In its most convenient and economical form, such a facility could be included within the circuitry of the limiting amplifier/demodulator IC as, for example, in the RCA CA3089E of 1974.

The growth of solid-state technology

Techniques evolved in the 1960s for the manufacture of IC chips, in particular those for the deposition of precision patterns of metallisation on a substrate, lent themselves also to other purposes, of which one of the more unexpected was that of the surface acoustic wave or ladder filters used as replacements for band-pass tuned circuits.

Ceramic ladder filters. From the manufacturing point of view, a significant disadvantage of an FM tuner, in comparison with a more conventional AM one, was that any FM receiver design will use a relatively large number of tuned circuits in the RF, mixer, oscillator, IF and demodulator stages.

All of these would need to be correctly adjusted during the manufacture of a commercial receiver, which would be a labour-intensive, time-consuming task. The availability of pre-tuned piezoelectric band-pass filter circuits therefore filled an urgent need, especially since the pass-band characteristics would be reproducible and could well be superior to those available from a conventional pair of band-pass, coupled tuned circuits.

Their method of operation, shown in **Fig. 3,** is based on the fact that an interlaced (interdigital) pattern of transverse conductive stripes on the surface of a thin wafer of piezoelectric material can be made to launch a surface ripple (the surface acoustic wave) in response to a specific input RF signal. This ripple passes down the wafer and induces a voltage in another interdigitated group of metallised stripes further along the wafer.

By adjusting the number of metallic stripes, the spacing between them and the extent to which they interleave, the RF pass-band of such an electromechanical filter can be very precisely controlled. It is customary to terminate the ends of the ceramic wafer with some mechanically absorbent material to avoid unwanted end reflections and the reverse face of the wafer may be similarly treated, although it is said that 95% of the energy remains within one acoustic wavelength of the surface.

Various materials are employed for such ladder filters, such as barium titanate, aluminium nitride and lithium niobate. These have acoustic velocities in the range 2000-5000m/s and the spacing between the adjacent metallic digits will usually be of the order of half a wavelength, depending on the design type, the pattern of metallisation depending on the transmission characteristics required. The method of construction of some types of these devices have been shown by Murray and White[5,6].

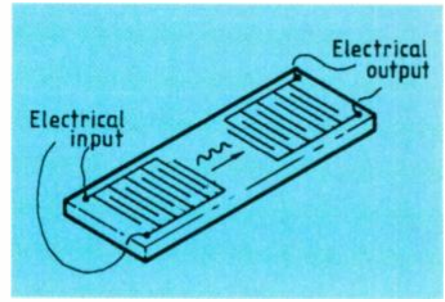

Fig.3. Basic construction of surface acoustic wave filter.

Filters of this general type have been available at least since the middle 1960s and are currently offered, for a variety of applications, by a number of manufacturers, such as Brush-Clevite, Murata, Philips, Toko, and Vernitron. **Figure 4** shows typical pass-band characteristics for a ceramic ladder filter intended for use in a 10.7MHz FM IF strip. The actual performance will be influenced by the source and load impedances employed, which may typically be in the range 200-330Ω.

RF transistors. At the time of the 1960 circuit design by Harvey, to which I referred at the end of the first part of this article, the HF transition frequency of the best available transistors was inadequate for RF amplification purposes in the 100MHz band. The author therefore adopted a circuit which avoided the need for an RF stage, though this limited the receiver sensitivity and could have increased the leakage of unwanted radiation at the local- oscillator frequency.

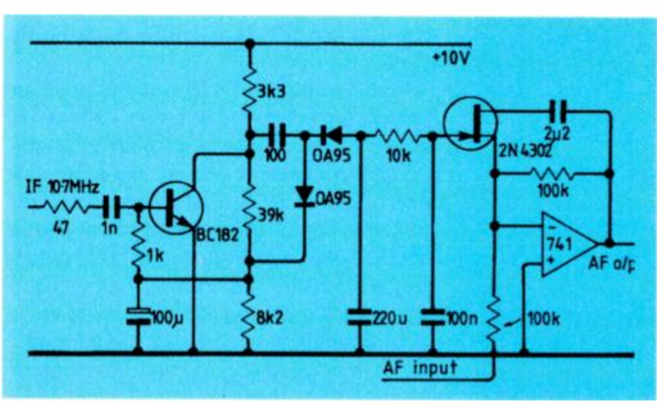

Fig.2. Automatic noise muting circuit operated by IF output signal strength.

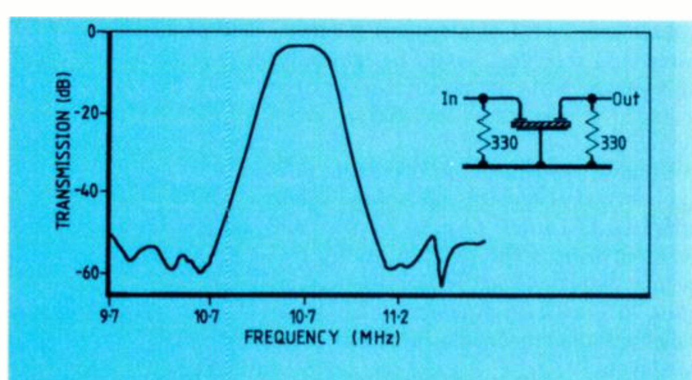

Fig.4. Transmission characteristic of FM IF ceramic filter.

Even when transistors with better F_t values became available, problems of instability due to internal feedback were still difficult to avoid, without complex neutralisation circuits. The use of a grounded base RF transistor stage of the kind shown in **Fig. 5** avoided the problem and this method was widely used for many years in inexpensive tuner-head systems, although the high degree of damping of the input circuit reduced image-channel rejection.

What was needed, clearly, was a transistor equivalent of the screened-grid valve, in which there was effective capacitive isolation between the input and output electrodes. The early experimental Alcatron, a germanium dual-gate junction fet described by Martin[7]) in 1961, clearly offered the possibility of internal electrostatic screening, although it was constructed using rather primitive alloy diffusion technology.

Although, many years before, Shockley and others had envisaged a transistor in which current flow through a depleted semiconducting channel could be augmented by an externally induced electrostatic charge, attempts to make such devices work had been frustrated by the difficulty in achieving the necessary degree of purity at the insulator-channel gate junction.

These practical problems were solved in the early 1960s and single insulated-gate mosfet transistors became available in 1963-4. Amplifier and oscillator designs using these were described by Butler[8] in 1965 and an RF/mixer stage for an FM tuner using mosfets was described by Rohde[9] in 1966.

While these single-gate mosfets had excellent RF characteristics, they had a significant internal gate/drain capacitance, which meant that RF amplifier stages using these devices needed some form of neutralisation to avoid instability, unless the stage gain was kept low. Source/gate capacitive isolation was provided by the dual-gate mosfet, introduced by RCA and others a year or two later.

Figures 6a and **6b** show the circuit symbol and constructional form of the dual-gate mosfet. Modern devices of this type offer signal-gate mutual conductance values in the range 2-12mS and gate 1 to drain capacitances as low as 0.01pF, coupled with a relatively high output impedance of more than 50kΩ.

It is customary to incorporate a pair of back-to-back zener diodes on the chip to protect each gate from possible electrostatic breakdown, as indicated in **Fig. 6c**, though these are usually omitted in the circuit symbol.

Although the noise figure and resistance to cross-modulation of these devices are slightly worse than in junction fets when used in similar type circuitry, the enormous convenience of these devices in RF amplifier and mixer stages has made them exceedingly popular with designers. An elegant FM tuner using them was described by Nelson-Jones[10,11] in 1971. This circuit also employed ceramic ladder filters in the IF stages and is, in many ways, typical of modern FM tuner design practice.

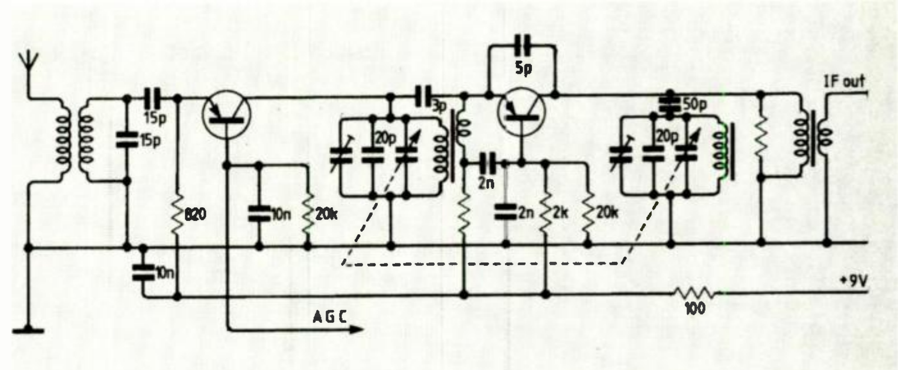

Fig.5. Low-cost tuner-head design of 1967, using self-oscillating mixer.

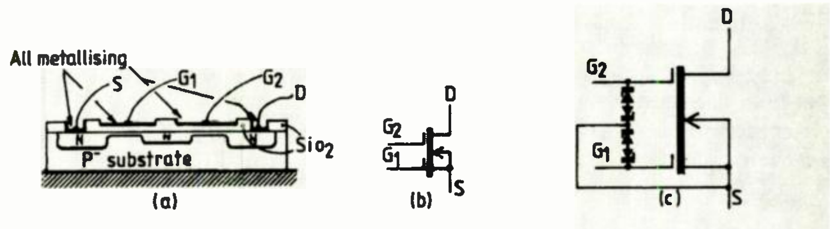

Fig.6. Structure and circuit symbol of dual-gate depletion-type mosfet.

Tuner head units. Although Nelson-Jones took the somewhat bold step of designing his own RF and mixer stages, it was by this time, becoming increasingly common for both manufacturers and amateur constructors to rely on specialist suppliers for complete pre-aligned tuner-head modules, based on grounded-base junction transistors, neutralised junction fets or mosfet RF stages, with either junction fet or mosfet mixers.

These head units used either ganged air-spaced tuning capacitors or more often Varicap diodes, because these would simultaneously tune a greater number of tuned circuits, in the interests of better image channel rejection and s:n ratio, and would also facilitate the use of automatic frequency control. However, the reverse voltage/capacitance characteristics of these tuning diodes needed careful matching.

A very popular tuner head module at the time was the Mullard LP1186 Varicap-tuned unit. An FM tuner design based on this head unit, described by Skingley and Thompson[12], used the thermal correction circuit of **Fig. 7** to compensate for the temperature dependence of the Varicap diode capacitance. This circuit also used an ingenious AF output-muting circuit operated by amplitude-modulated components in the IF output.

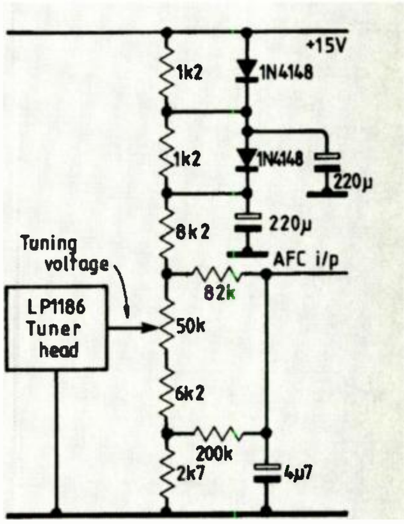

Fig.7. Skingley and Thompson Varicap-diode thermal compensation.

IC IF and demodulator stages

The process of simplification by the use of pre-aligned tuner-head modules and ceramic-filter IF tuning blocks continued with the development of ICs for IF amplification and demodulation. **Figure 8** shows the Motorola MFC4010A IF amplifier block of 1968 and the MC1351P limiting amplifier/demodulator of 1969 is

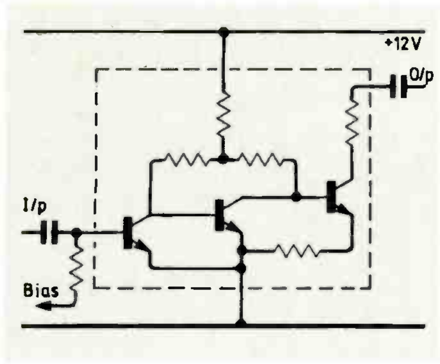

Fig.8. Motorola MFC4010 IC RF gain block.

shown in **Fig. 9**.

By this time, demodulator systems such as the Foster-Seeley and ratio-detector had been superceded by this type of single-coil gate-coincidence detector circuit. RF signals are amplified by the transistor chain Tr_{1-9} and fed to one port,Tr_{15}, of the transistor chain Tr_{11-17}. A second RF signal, derived from the single tuned circuit L_1C_1, is fed to the second port, $Tr_{11,14}$, via the buffer emitter follower Tr_{10}.

If there is no signal to Tr_{10}, or if this signal is in phase quadrature with the incoming RF signal (the condition that exists if L_1C_1 is loosely coupled to the RF input signal and is tuned to the same frequency) the current flow through the transistor chain is equally divided between $Tr_{11,13}$ and $Tr_{12,14}$, and there is no change in the current flow through R_{20}.

If, however, the phase of the RF output from L_1C_1 is caused to shift away from quadrature by a change in the input frequency, there will be a change in the mean current through R_{20} and a consequent RF-frequency-dependent output signal.

This can provide a low distortion (0.3-1.5%) demodulation system for an FM signal, which only requires the adjustment of a single tuned circuit, which could be replaced by a suitable fixed-frequency ceramic resonator.

In the circuit of **Fig. 9**, transistors Tr_{1-9} form a high-gain RF amplifier block, in which amplitude clipping is achieved by limiting the possible collector voltage swing to about 1.8V p-p. This method of amplitude limitation, by driving the transistors into saturation, is less good than the back-to-back diode technique adopted in the RCA CA3089E and the later CA3189E.

3089 and the 3189

A major requirement for an FM IF amplifier/demodulator system is that there should be enough IF gain to cause limiting at an aerial input voltage of less than 5mV, to allow adequate performance in fringe areas. In practice, this probably implies an IF input sensitivity, at the lim-

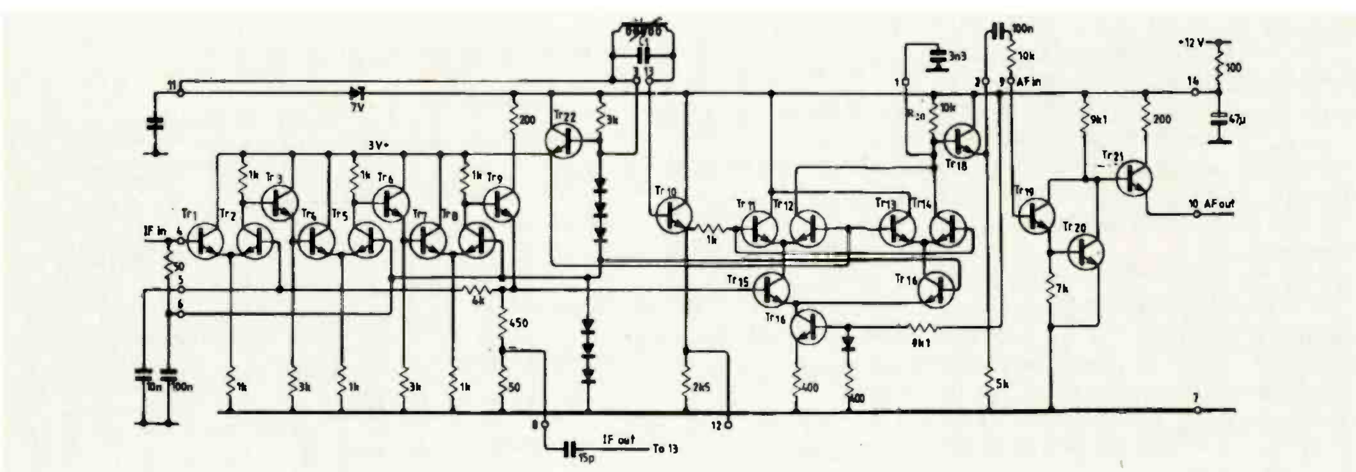

Fig.9. MC1351 FM IF strip and demodulator.

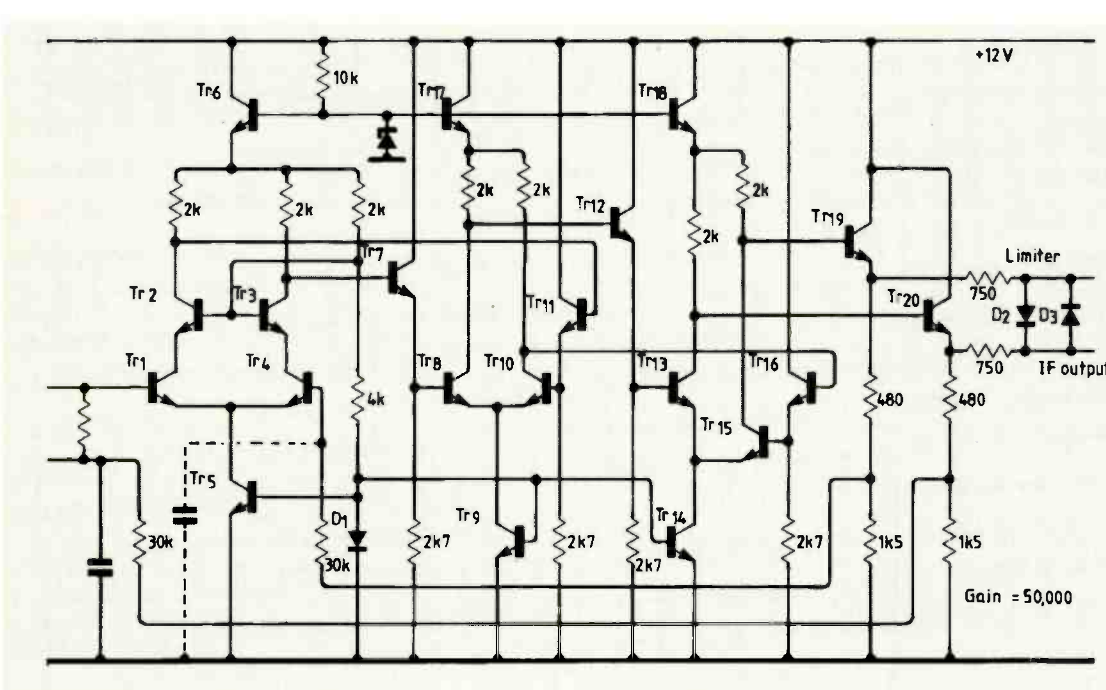

Fig.10. Limiting IF amplifier gain block used in RCA CA3089E.

iting threshold, in the range 10-50mV.

It is also desirable that the demodulator circuit should have a distortion level of 0.5% or lower, that it should be simple to adjust, that the recovered audio output voltage should be 0.5V RMS or more to operate stereo decoder circuitry without further amplification and that facilities should be provided for AGC, AFC, inter-station noise muting and some method of tuning indication.

All these needs were met, for the first time in a single IC, with the introduction in 1971 of the RCA CA3089E, which uses the very highly developed IF amplifier circuit shown in **Fig. 10**. A cascode-connected input long-tailed pair Tr_{1-5} feeds two further stages of symmetrical push-pull amplification Tr_{7-20}, which drives the gate-coincidence detector via the back-to-back diode limiter mentioned above.

Each of the RF amplifier stages is also arranged to feed a current summation circuit to allow both a tuning meter and an inter-station noise mute circuit to be operated from an output voltage largely proportional to the size of the input IF signal. This circuit also provides a control voltage for an AGC system which can be used, where appropriate, with the RF and mixer stages of the tuner head. An AFC voltage is derived from a secondary output from the gate coincidence detector.

Although this IC is still widely used, an improved version, the CA3189E, was introduced by RCA in 1977. It gives a 5dB improvement in stereo signal-to-noise ratio and an improved inter-station noise muting circuit, in which a DC signal related to the IF frequency deviation was added to the signal-strength control voltage to improve muting operation at frequencies close to a high-level channel.

This later IC has been exceedingly successful commercially. Because of its excellent performance, it has imposed a degree of design conformity in the choice of amplifier and demodulator method used in contemporary designs, although it is still practicable to use this IC in non-standard FM circuitry, such as a recent phase-locked loop design of my own[13,14].

In the final part of this article, I will look at the techniques used for the broadcasting and reception of stereo signals, together with some of the recent innovations in commercial receiver design.

Editorial survey: use the information card to evaluate this article. Item N

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CIRCLE NO. 153 ON REPLY CARD

ACTIVE

Discrete active devices

700MHz building block. Monolithic OPA660 is a voltage-controlled current source and voltage buffer. Buffer stage has a 700MHz bandwidth, 3kV/µs slew rate and rise time of 1.5ns for 5V step. Uses include signal-processing stages in video systems, radar, communications and high-speed data acquisition. Burr-Brown International Ltd, 0923 33837.

BJ transistor model. Bipolar junction transistor software model can simulate small and large signal performance of microwave silicon devices as well as presenting bias-dependent s-parameters for linear simulation at any arbitrary bias point. EEsof 49 81 052 4005

Mosfet relays. Opto-coupled mosfet relays have bounce-free switching and provide up to 2.5kV isolation. Standard six-pin DIL package; less than 0.5g. It can switch up to 400V at currents to 1A. AC and DC versions. Switching times are down to 18µs and input sensitivities up to 4mW. NEC Electronics (UK) Ltd, 0908 691133.

Microwave transistors. Semelab is starting to make microwave transistors and full production is planned for later this year for the previous Acrian style devices and newly developed 2GHz mosfet range. Semelab Ltd, 0455 554711.

IGBTs. Saturation voltage is typically 2.2V and current range is 15 to 400A. 600 and 1200V versions. A high short-circuit capability, latch-up free, improves ruggedness. 600V units have a fast recovery diode to improve turn-on losses and reduce RFI problems (available on 1200V units later this year). Toshiba Electronics (UK) Ltd, 0276 694600.

Automotive mosfets. The 2SK943 mosfet for the automotive market is a 60V 25A device with a typical on-resistance of 46mΩ in an isolated TO220 package. Logic level compatible gate drive makes it suitable for direct interface to cmos and TTL logic circuits. Toshiba Electronics (UK) Ltd, 0276 694600.

Mosfet. N-channel dmosfet has a power rating of 360mW when mounted on a substrate 10 x 8 by 6mm. The SOT23 BSS123 device has a drain-source breakdown of 100V with typical on-resistance of 5Ω. Maximum pulsed drain current is 0.68A. At 1mA drain current, gate-source threshold voltage is 2.2V. At 25V and 100mA, transconductance is 120mS. Zetex plc, 061-627 4963.

Linear integrated circuits

Motor driver. A 5V voice-coil motor driver IC with sense-fet outputs, the A8932CLB mixed signal IC is for positioning read and write heads in hard disk drives for laptop computers. It also integrates a full-bridge current amplifier onto a single chip. Allegro MicroSystems, 0932 253355.

Communications IC. Frequencies of Fujitsu Super-PLL communication ICs start from less than 0.5GHz for cellular radio up to 2.5GHz for digital TV. Power consumption is 10mA. They can operate from 2.7 to 5.5V supplies at -40 to +85°C. Hawke Components Ltd, 0256 880800.

Operational amplifier. Micropower op amp needs 1.2µA maximum supply current and operates from single supplies ranging from 2 to 10V, or from dual supplies of up to +5V. The output of the Maxim MAX406 can source 2mA when powered from 9V. Eight-pin devices in plastic DIPs SO and CERDIP packages. Kudos Thame, 0734 351010.

Telephone IC. TEA1085 works in line-powered sets, with a loudspeaker in the base as well as handset, to let several people listen to a conversation. 40mW into a 50Ω speaker in BTL or 20mW in SE configuration. Loudspeaker amplifier with fixed 35dB gain. Philips Components, +31 40 724173.

Microprocessors and controllers

VGA display controller. VGA display controller improves Windows and Presentation Manager performance on 386 and 486 PCs and workstations. The 77C22E chip provides 16-bit operation in all display modes and interfaces to AT, eisa and Microchannel systems. NCR Microelectronics Europe, 0049 89 632202.

Optical devices

FDDI chip set. AMD is sampling an integrated circuit chip set for fibre distributed data interface (FDDI) lans. The Supernet 2 chip set allows implementation of a complete FDDI station on an AT half-card or similar sized board. It supports 400Mbit/s memory bandwidth. Drives fibre or copper. Advanced Micro Devices, 0483 740440.

Optical-fibre system. Toslink fibre optic system from Norbain can transmit signals at distances up to 10km. It is suitable for PCB mounting and simplex or duplex connectors. Applications include NC machines and transmitting data between factory machines. Norbain Technology, 0734 864411.

Laser diodes. Optilas range has source sizes of 100 x 1µm, 200 x 1µm, 1cm x 1µm, and 0.1 x 75µm. LDT26000 has output powers from 125mW to 1W at 790 to 812nm. LCW5100 units are monolithic arrays with up to 10W continuous output power. LCW100 and 200 have wavelengths from 800 to 870nm and output powers from 250 to 500mW. Optilas, 0908 221123.

Photo sensors. TLP820 has a 5mm detection gap, a 50mA direct forward current, and 35V current emitter voltage. The 860 needs 1mA maximum for led forward current. 1200 is for use as a general purpose photo interrupter with a connector, and the 1224 is for use in 24V systems and is rated to 95°C. Toshiba Electronics, 0276 694600.

Programmable logic arrays

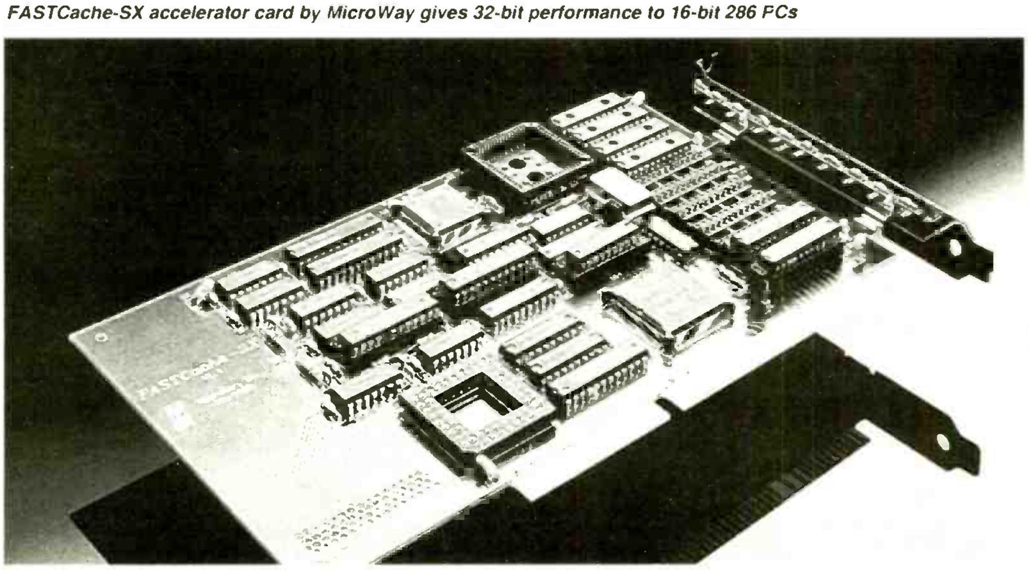
Gate arrays. CG31 units are sea-of-gate devices with 130,000 to 200,000 gates. They are made in 8µm technology and three versions: 129,540 basic cells and 300 signal I/Os; 160,930 basic cells and 332 signal I/Os; and 201,188 basic cells and 332 signal I/Os. 70% of the basic cells are typically available to the user. Gate delay is 370ps. Fujitsu Microelectronics Ltd, 0628 76100.

ECL gate arrays. ECL gate arrays with an internal flip-flop frequency of up to 4GHz have a clock frequency of more than 1GHz and a gate switching time of 75 to 160ps. Internal logic of the ICs consists of basic cells that include a master and slave circuit. Fujitsu Microelectronics Ltd, 0628 76100.

GaAs gate arrays. Fury MB5xxx GaAs gate array units have inputs that can work with ECL, TTL and GaAs signal levels. Gate delay time is 70ps, gate power consumption 1.1mW, and input signal frequencies are up to 1GHz. Fujitsu Microelectronics Ltd, 0628 76100.

Motor drive IC. LMD18200 IC can drive up to 0.25hp DC motors; two can drive a high power stepper motor circuit. It contains four power mosfets, four fast power diodes and can drive four large capacitive load mosfets at high speed (two being highside switches). It also provides low loss current sensing, shorted load protection and thermal shutdown and warning. STC Electronic Services, 0279 626777.

FASTCache-SX accelerator card by MicroWay gives 32-bit performance to 16-bit 286 PCs



PASSIVE

Passive components

Resistors. A range of high precision resistors for up to 40kV or 1000MΩ applications have resistance tolerances from ±10%. Epoxy coated to minimise flashover and breakdown problems. Power dissipation is 0.8 to 3W at 20°C. Temperature coefficient is 150ppm/°C from -55 to +125°C. Menvier Hybrids Ltd, 0295 256363.

Capacitors. ZA series have a leakage current of 0.004CV or 0.2μA. They are for measuring instruments and audio devices where low noise is required and operate from 6.3 to 100V at capacitances from 0.47 to 47μF, tolerance ±20% at 120Hz, 20°C. Operation is rated between 40°C and +85°C. Radial packages. Nichicon (Europe) Ltd, 0276 695393.

Ceramic capacitors. Threaded bushing units have working voltages of 100, 200, 250 and 500V DC covering capacitances of 75 to 10,000pF. Solder mount types go from 100 to 300V and 47 to 6000pF. Discoidal units are rated at 500V and 33 to 1000pF. STC Mercator, 0493 844911.

Connectors and cabling

Five way/42 way din style connector. Erni GmbH's special size, DIN 41612 style connector has raised mounting flanges, enabling it to fit between two standard length DIN 41612 connectors on a double Eurocard in existing mounting holes. Two versions: one for use with up to 42 signal contacts rated at 4A; the second will accept up to five high current 40A contacts, or a similar number of coaxial or fibre optic contacts. Radiatron Components Ltd, 081 891 1221.

Wire to board. NR series low profile wire-to-board connectors insulation displacement products have a height above board of 13.1mm. Height for crimp types (XH series) is 9.8mm. Both have a 2.5mm pitch and use the same base post assemblies available in top or side entry forms. Contact resistance is initially 10MΩ, rising to 20MΩ after environmental cycling. XH 3A, can be supplied with up to 20 poles; NR, 2A, up to 13 poles. 250V AC/DC with an insulation resistance of at least 1000MΩ. Takbro Ltd, 0444 245601.

High current terminal block. 30A, 500V terminal block 8375 is designed to accept 4mm^2 cable. It has a double square profile solder pin, offering greater mechanical support than conventional units. The solder pin is copper/tin plated. Enclosed housing interlock gives 7.5mm pitch. Wieland Electric Ltd, 0483 31213.

Tek FiberMaster is the only OTDR to accommodate two dual-wavelength optical plug-ins at the same time

Displays

Led display array. Gunstar array has 16,384 leds in an area 42.3 x 42.3mm in a 66 x 60 by 6.7mm package. Each diode is a pixel which can independently present any alphabetic, numeric or graphic display required. MIL883 requirements. Two ceramic substrates mounted on top of each other are contained in a hermetically sealed metal package with a transparent lid. Contraves Circuit Technology, 0908 222466.

Instrumentation

Cable detector. Intek TEK600 hand-held detector has automatic adjustment of sensitivity and will detect dead or live cables through various materials including foil-backed plasterboard. 9V battery. 50 x 64 x 30mm. Detection depths are 12 to 25mm for twin and earthed cables and 6mm for telecomm/computer cables. Alpha Electronics, 0942 873434.Alpha Electronics 0942 873434

Battery oscilloscope. Hitachi's V209 portable, miniature and battery-powered oscilloscope comes with x1 and x10 probes and has a screen area of 8 by 10 divisions. Vertical deflection factor ranges in ten calibrated steps from 1mV to 5V per division. Horizontal sweep times are 0.5μs to 0.2s in 18 steps. Feedback T&M, 0892 653322.

Function generators. Thandar TG2000 units have 0.002Hz to 20MHz frequency ranges in eight overlapping decade ranges with adjustments via coarse and fine verniers. They also offer sine, square and triangle waveforms as well as TTL outputs. Feedback T&M, 0892 653322.

Digital storage oscilloscopes. 4060 family of DSOs, two and four channel versions, has 400megasamples/s sampling, 8-bit vertical resolution, 150MHz bandwidth, 16 non-volatile memories for waveform storage, on-screen signal measurement and analysis functions, and internal hard-copy capabilities. Gould Electronics Ltd, 081-500 1000.

Digital multimeters. The 175A 4.5 digit autoranging instrument has 10μV DC and TRMS AC sensitivity, resistance measurement down to 10mΩ, DC and TRMS AC current resolution from 10nA, and a dB function with internal reference to 600Ω over a 100kHz bandwidth. 197A is a 5.5 digit version with resolutions of 1μV, 1mΩ and 1nA. Keithley Instruments Ltd, 0734 575666.

Digital multimeter. Full rack capability in half rack size is a feature of the SI7063. The 6.5 digit unit includes pulse width conversion techniques to provide continuous averaging and linearity on 20 measurement functions at up to 1000 readings/s with no intervals between measurements and no polarity reversal errors. PPM Instrumentation Ltd, 0483 301333.

OTDR. Two dual-wavelength optical plug-in modules can be accommodated in the FiberMaster optical time domain reflectometer giving flexibility of high resolution and long-range performance in single and multimode applications. Driven by Motorola 68020 32-bit technology. Tektronix UK Ltd, 0628 486000.

Real-time oscilloscope. Hitachi VC6024 'scope combines real time and digital storage. 20Msample/s, real-time bandwidth is 50MHz. In digital storage mode it can capture repetitive events up to 50MHz and single-shot events to 5MHz. Memory length of 2000 words on each channel. Thurlby-Thandar Ltd 0480 412451.

Scope and monitor. 5851V vectorscope and the 5861V waveform monitor are half-rack instruments. The vectorscope displays relative amplitude and phase of chrominance components with an accuracy of ±2%. The monitor measures signal amplitude, timing and frequency response. Thurlby-Thandar Ltd, 0480 412451.

DMM scanner. An eight channel scanner for BCT's PC-based digital multimeter combines Vip board and software to support eight intelligent multimeters linked to a PC. It functions as an intelligent DMM using PC graphics software, mouse and plug-in card, and can measure voltage, current, resistance, decibels and capacitance. Measurements can be stored. Scanner allows selection of a different function and range for each channel. Four scanners can be linked. £175. Blue Chip Technology, 0244 520222.

Harmonics module. The harmonics expansion module for Vip system 3 gives a solution to harmonics measurement, with the module providing simultaneous three-phase monitoring of current and voltage - allowing printed and displayed information up to the 25th harmonic. Vip system 3 is configured for harmonics analysis by inserting a plug-in expansion module into the slot at the rear of the instrument. The instrument includes an oscilloscope-like waveform display. Elcomponent Ltd, 0279 503173.

Measuring amplifier. MGC measuring amplifier combines analogue and digital technologies. A patented A-to-D conversion technique ensures the analogue signal is digitised without losing information by gate-array technology. Functions include filtering, taring, and balancing of the mean point signal. It is designed to accommodate plug-in units, those available being intended for direct-voltage signals and thermocouples, strain gauge transducers and inductive transducers. Hottinger Baldwin Messtechnik, 0869 321321.

Interfaces

Transducer interface. Oasis interface connects a microcomputer RS232 port to analogue signals from transducers such as load cells, strain gauges, LVDT, PH probes and oxygen probes. Input impedance is 10 or 1000GΩ with switch selectable gain of 1, 10, 100 or 1000. 3D Digital Design and Development Ltd, 081-886 3668.

Lan interface circuit. MB86951 encoder/decoder is a serial interface cmos device for PC-based Ethernet systems. MBL8392A coaxial transceiver interface IC transceiver device is for Ethernet lan applications. The MB86954 microchannel interface unit. Fujitsu Microelectronics, 0628 76100.

Multimedia interface. Rave (real-time audio and video environment) multimedia development environment and user interface for the IBM-PC is for industrial uses such as process control and instrumentation. It runs on top of the OS-9000 operating system. Microware Systems (UK) Ltd, 0489 886699.

Production test equipment

Wafer inspection. Nidek IM-7 inspects etched wafers during photo-lithographic processing. Its fused quartz contact surface gives pin-point accuracy of movement. Stabilised auto-focus eradicates focusing problems, even with dark or bright visual fields and highly absorbent or reflecting surfaces. Wafer exchange time is 2.5s/wafer. Manual positioning by integral joystick. Dage (GB) Ltd, 0296 393200.

Board testing. BoardMaster TSA offers an open architecture test strategy for in-circuit, functional and combinational testing up to data rates of 50MHz and offers manufacturing defect analysis, analogue/digital in-circuit, emulation, simulation, combinational and functional testing. It links to all professional simulator target systems. Rohde & Schwarz UK Ltd, 0252 811377.

Digital IC tester. Designed around a Z80A 8-bit microprocessor, the ABI digital tester system features dedicated LSI ICs to control keyboard and display, and handle information input/output from the device under test. It can cater for clocked devices such as flip-flops, latches, counters, and shift-registers, tri-state or open-collector devices, memories, and interfacing including line drivers, receivers, and opto-isolators. STC Instrument Services, 0279 641641.

Appliance tester. Seaward PAT 1000 portable unit can be used for earth continuity testing; insulation testing to 500V DC; flash testing selectable between 1.5kV Class I and 3kV Class II; a supply voltage load test with a current limit; operation test from 0 to 3.2kVA at supply voltage; and leakage test. A memory permits recording of up to 400 sets of tests. STC Instrument Services, 0279 641641.

Power supplies

Switching 40W. Power General Flu3-40 series of universal input, triple output, 40W switching power supplies is available in six models with output combinations of 5, 12, 15 and 24V DC. UL, CSA, IEC and VDE approved. Input range is 85 to 265V AC, 100 to 370V DC. On-board input line filter exceeds VDE/FCC class B requirements by about 15dB. Dowty Power Electronics, 0722 413060.

DC/DC converters. DB DC/DC converters, with short-circuit protection facility and automatic reset, have three input voltage ranges — 10 to 16V, 17 to 34V and 35 to 70V. These 50W open-frame primary switched regulators offer up to three isolated output lines in combinations of 5, 12, 15 and 24V. Schroff UK Ltd, 0442 40471.

Power supply controller. Kikusui's unit simplifies the making of automatic DC power supply systems, either via GPIB or sequential control. In GPIB mode it interfaces between host computer and power supply. Two channels; two supplies can be controlled. Setting resolution is 12bit for each output. Telonic Instruments 0734 786911

High-current supply. Kenwood PD18-10 is a 0-18V and 0-10A unit with dual analogue or digital meters and a three-terminal floating output. Voltage setting is via a ten-turn potentiometer. Preset output voltage can be switched. Ripple and noise between 10Hz and 1MHz are within 0.5mVRMS. Thurlby-Thandar Ltd,0480 412451.

Computer power supplies. Computer Products power supplies include linear, switched mode, Euromodular, and bench adjustable units as well as DC-DC and AC-DC converters. Most have approval to UL, CSA, VDE, ISO9001 and IEC950 standards. Verospeed, 0703 641111.

Radio communications products

Network analyser. A standing-wave ratio bridge makes this device suitable for simultaneous measurement of transmission and reflection characteristics of components for mobile communications systems. R3763A covers the range from 300kHz and has a sweep time of 0.5ms per point. Advantest UK Ltd, 081-336 1606.

Radio ID system. ID2 measures 42 x 32mm and works by sending a two-digit ANI signal at the end of each over. It is programmed by splash pads for any of 256 identities and has only five connections to the radio, taking minutes to install. Communication Development Specialists Ltd, 0256 83528.

Single unit tester. Marconi 2955R radiocommunications test set has all functions for transceiver testing in a single unit. It can test AM, FM and PM mobile radio equipment to 1000MHz including low power hand portables using selective calling, full duplex radio telephones, digital pocket pagers, base station and repeater equipment. IR Group, 0753 580000.IR Group 0753 580000

Power supplies

-48V to +5V DC-DC converter. Max650 produces a regulated +5V 250mA output from -48V. All control functions and a 140V, 250mA pnp transistor are on chip. It incorporates a shutdown function to permit output to be disabled under logic control. Soft start reduces initial current levels, and permits safe start-up at full load without overshoot. Maxim Integrated Products, 0734 845255.

Lower cost. AEC series low cost unregulated power supplies have AC inputs of 110, 220 and 240V, frequencies of 47-440Hz. Load regulation is 20% or 3V whichever is greater for a 10-100% load change and output ripple and noise 1V RMS. Operating temperature is 0-70% with 2.5%/°C derating above 50°C. Isolation 4kV. Ten units can be connected in series or parallel. XP plc, 0734 845515.

Programmers

Software upgrade. Intel Flash parts can be handled on Stratos PC-based eprom programmers using a software upgrade in the form of a floppy disc. It extends to full E2 support in 24, 28 and 32 pin packages. Stag Microsystems Ltd, 0707 332148.Stag Microsystems 0707 332148

Transducers and sensors

Transducers. Isotran transducers are for measuring AC electrical variables such as current, voltage, power and VARs. Accuracy is typically 0.2% of full scale. There are two case sizes, either 55 or 150mm wide DIN rail or panel mounted. Isolation is 4kV on input to input and input to output. Glade Instruments Ltd, 0785 662685.

Alarm thermometers. Therma D40/R panel alarm thermometers are general purpose mains (240 or 110V) operated units. They are a digital indicator with an on/off high or low alarm/switch rated for 8A loads. Led display indicates set point or the temperature, with set point adjustable from front panel. -50 to +1150°C with 1°C resolution, repeatability and accuracy. Probes from £10.00. ETI, 0903 202151.

Single-axis brushless servo. PS7X is supplied ready-to-run, containing an all-digital indexer/drive unit with built-in power supply, brushless motor with integral encoder, and 10ft interconnection cables. The motor can handle peak torques of up to four times its continuous rating and has a top speed of 7500rpm. Motors are proprietary two-phase brushless designs using rare-earth magnets to create the high air-gap flux density needed for optimum torque and efficiency. Parker Digiplan Ltd, 0202 690911.

Displacement transducers. D5-W miniature displacement transducers, developed for submersion in liquids or gases, are hermetically sealed using electron-beam welding of the stainless steel housing. Specially designed cable attachments will withstand pressures of 2000psi. Measurements from ±1 to ±5mm. RDP Electronics Ltd, 0902 457512.

Vision systems

Image processor. Imaging system provides digital storage, real-time processing and playback of video sequences for industrial and security CCTV systems. It uses transputer technology and captures images from pal standard signals, then examines them for specific features such as moving objects or characteristic shapes. It stores the images in four 512 by 512 8-bit memories for further processing. Akebia 081-546 4908

COMPUTER

Computer-aided design

Cad program modules.. Release 1.03 of the HEPA series of cad program modules is for switching RF power amplifiers and linear amplifiers driven into gain saturation. They evaluate performance from RF power transistors and design, simulate and optimise the power amplifier circuit. Claimed to be faster than Spice by a factor of 1000. Design Automation Inc, 617 862 8998.

Computer board level products

Grabber board. Analogic FG/ALU-8 video frame grabber board for the PC/AT is capable of real-time 8-bit ALU processing and uses a menu-driven dedicated software package called Imagine. It has RS170, RS330, NTSC, pal and CCIR compatibility. Consort Electronics, 0252 871717.

Digital signal processor
DSP module. SPT156 measures 9 x 11cm and is built to the Inmos Tram format. Its dual processing design combines the 10Mips power of the T400 or T805 transputer with the DSP capability of Motorola's DSP56001 processor. 1 or 4Mbyte of dram as system memory and 96Kbyte of fastsram. Sunnyside Systems Ltd, 0506 460345.

Image capture card. Entry level multimedia card MicroEye IC can capture a video image and incorporate it into a PC graphics display. It has been enhanced to accept single field video images from video recorders which eliminate the flicker experienced when capturing pictures from a moving video source. Digithurst, 0763 242955.

Solid state disc. PC form-factor plug-in cards perform all the functions of conventional floppy or hard disks with access times 50 times faster than a hard disk. For use where a PC is used for fixed tasks such as machine control and monitoring, they can also let networked PCs boot without a floppy disk. Fairchild Ltd, 042121 6527.

Single-board computer. XP 286 and 386 single-board computers are software compatible with the PC and AT and have full VMEbus master/slave interface and system controller functions. They run at 16 or 20MHz. Local system memory is either 512Kbyte or 2Mbyte dram expandable by daughter card to 4Mbyte. HTEC Ltd, 0703 581555.HTEC 0703 581555

performance. Based on a 16MHz 80386SX microprocessor, it keeps hardware and software compatibility with existing 16-bit systems and lets AT users run multitasking operating environments such as Unix386, DESQview 386 and Windows 3. Microway (Europe) Ltd, 081-541 5466.

Development board. Cmos microcomputer development board for the Mitsubishi M50747 works with a PC running a text editor, assembler and appropriate communications software. The board carries an M50747SP extended microcomputer, 8Kbyte of battery supported ram, 16Kbyte of eprom, reset, crystal clock and RS232 transceiver in a 100 x 160mm board. RCS Microsystems Ltd, 081-979 2204.

Computer systems

Rack-mount computer. PC825 rack-mount computers can act as low-cost SBC stand-alone controllers or file servers and data acquisition and management computers. Features

Industrial workstation. 2900-RM is rack-mounting with an integral 19-in colour screen. Complex plant mimics or trend graphs can be displayed in up to 1024 x 768 Super-VGA resolution. It is based on the 386SX or DX processor with 1Mbyte ram, one 3.5-in floppy disk and 40Mbyte hard disk with 19ms access time. Front and rear connectors for keyboard. 110V/60Hz or 220V/50Hz. £5000. SD-Scicon UK Ltd, 061 491 3683.

Development and evaluation

In-circuit emulators. IceMaster in-circuit emulators replace the Microlce and Metalce units. The IceMaster is for 8051 and 68HC11 microcontrollers and has a windowed user-interface. PC XT/AT or PS2 compatible. Reflex Technology Ltd, 0494 465907.

Software

PCB autorouter. Version 7.7 of the Vutrax PCB system includes full Unix compatibility under X-Windows, a gridless autorouter and schematic capture enhancements. Vuroute is a

above. Keithley Instruments Ltd, 0734 575666.

Autorouter. The Maxroute fully interactive shove router is available from Lloyd Doyle with a PADS interface. In routeing a board it looks for ideal paths that could be made available and then clears the room for the new route at the location. Lloyd Doyle, 0932 245000.

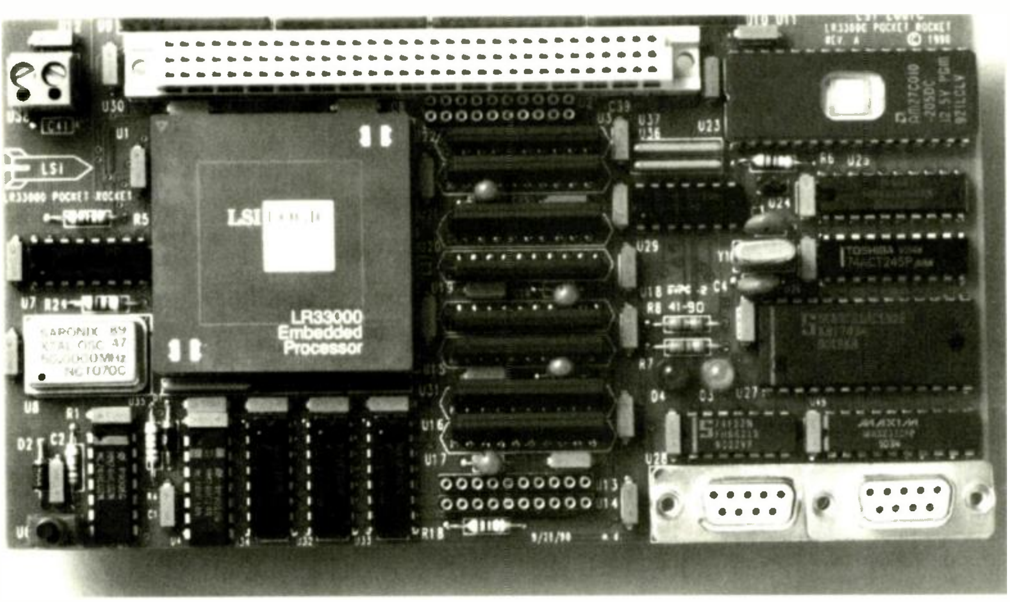
DSP toolset. InterTools 96002, for creating and debugging software applications for embedded Motorola DSP96002 processors, is a totally integrated C environment. It can implement advanced optimisations, in-line assembly and instruction coalescing techniques. Loughborough Sound Images, 0509 231843.

Development tool. Microtec has released an 88K software development tool chain to produce and debug highly optimised code. It addresses the Motorola 88100 and consists of C compiler, C source level simulator and debugger and assembler. The C compiler is fully ANSI conformant and takes full advantage of the 88100 risc architecture. Microtec Research Ltd, 0256 57551.

Schematic capture for large PCBs. An enhanced version of schematic capture software Pads-Logic is particularly suitable for large PCB designs. Upgrades include hierarchical design capability, design orientated database, automatic gating and pinning, and support for a range of popular simulation and cad layout tools including P-Cad, Futurenet, Cadstar, P-Spice and Susie. Library of 5000 electrical devices and parts. Lloyd Doyle Ltd, 0932 245000.

Data logging. Solar is a real-time PC based program for recording equipment signals. It has multi-tasking, fail safe power-down protection, password access control, graphical trend displays, help screen facilities, on-demand reports and data export. User-definable algorithms can be incorporated for calculating values prior to storage or display. Nano Computing Ltd, 0606 49937.

Workshop management. Scantrax, is designed to give control over administration of the repair workshop to minimise paperwork. It uses conventional keyboard and bar-code input to record receipt of repair items, job status, technicians' time and materials used. Full traceability of spares used and repair item history is retained. Orac Information Systems Ltd, 0734 772233.



Pocket Rocket from LSI Logic, an evaluation board for the LR33000

Evaluation board. An evaluation board for the LR33000 embedded processor, the Pocket Rocket, board measures 8.6 x 15.7mm. It can be used in hardware and software evaluation as well as for prototype assistance. It contains 1Mbyte of dram, 128kbyte of eprom, two serial channels and a 96 pin expansion counter. LSI Logic Europe PLC, 089 926 90 30.

Plug-in accelerator. The FASTCache-SX plug-in accelerator card from Microway enhances 16bit 286 IBM compatibles with 32-bit

include ISA, eisa or MCA motherboards, eight-slot eisa or 4 to 15 slot ISA backplanes, and four device drivers all with shock mounts. Comcen Technology, 0792 589988.

Industrial PC. 2902-FS industrial PC is for desktop use and has a 19-in screen. It uses the Intel 80386 and is drip proof and fan filtered in a rugged metal case. Disc drives and controls are protected by a locking cover. VGA graphics standards give up to 1024 by 768 super-VGA resolution with 16 colours. SD-Scicon UK Ltd, 061-491 3683.

gridless rip-up and retry autorouter with specific bus, routeing and optimisation phases for conventional and surface mount designs. Computamation Systems, 0525 378939.

Data acquisition software. For 386 and 486-based PCs Viewdac gives users access to features such as high processing speed, 32-bit addressing and multitasking. It uses a window environment and runs on Dos 3.0 or

Editorial survey: use the infomation card to evaluate this article. Item O.

Exploiting the spectrum above 30GHz

Despite R&D effort and official encouragement from the Radiocommunication Agency of the DTI, practical civilian utilisation of the radio spectrum between 30 and 60GHz for communications and broadcast distribution in the UK seems destined to proceed relatively slowly.

An identified practical application, however, is to link mobile cellular radio control centres and their base transceiver sites at 38GHz. GEC-Plessey at Coventry are to introduce later this year short-range 38GHz link equipment providing two 8Mbit/s digital channels.

But the future of 40GHz broadcast distribution systems (MVDS) seems less certain, with cable operators so far showing relatively little interest, despite field trials by BTRL (British Telecom Research Laboratories), IBA and industry.

Such at least appears to be the case from information coming out of two IEE colloquia ("Radiocommunications in the range 30-60GHz" and "The National Radio Propagation Programme") and the 26th Appleton lecture given by Roger Byrne (ITC, formerly IBA).

The IBA work on MVDS has included field trials in both millimetre-wave bands and the upper part of the 11.7-12.5GHz broadcast band reserved primarily for DBS.

The 40.5-42.5GHz band promises to be the harmonised frequency band for European MVDS: at 12GHz it is now recognised that there would be insufficient spare spectrum to provide a 20-channel MVDS system equivalent to modern broad band cable systems.

NTL (formerly IBA Engineering Division) is now concentrating on the possibilities for the 40GHz band. The newly-created ITC will issue "local delivery" licences to cable operators without specifying the technology, thus permitting cable or MVDS or a mixture of both to be used by franchise holders.

A working group has recently been formed by the Radiocommunications Agency of the DTI to assist the DTI, ITC, industry and potential users in formulating broad plans for the use of MVDS at 40GHz.

SE Pike and John Lothian (NTL) have pointed out that, despite limitations due to currently available technology and attenuation by rain and atmospheric gases (oxygen vapour), it is possible to obtain a useful cell size of about 3.8km. Using a monolithic low noise amplifier in the receiver would increase this to 5.6km and coverage would be achieved using a transmitter with a sector horn on one side of

Mobile comms confusion may deter users

Commercial success of the existing analogue Cellnet and Vodafone networks — over 1 million subscribers, though with growth rates currently affected by the recession — is seen as an encouraging sign for pan-European harmonised digital systems. But at a recent IEE colloquium, Dr Christopher Queree (MVA Systematics) warned that "the complexity and range of mobile communication offerings (present and future) is confusing to users and smacks of being driven by technology".

Dr Queree's worry was that, having chosen one mobile system a user will be reluctant to take another. Some key aspects of mobile services, such as traffic information, were not valued highly, he said, partly because at the moment the quality of such information is not as high as will be needed for effective real-time fleet control.

"In strictly cost-saving terms, the returns (to the user) of mobile radio services are often not brilliant," he said, and pointed to a US study of truck tracking suggesting a return of about 1% on an investment of around 5% of turnover.

Dr Queree concluded that success (of pan-European systems) will neither be guaranteed nor easy.

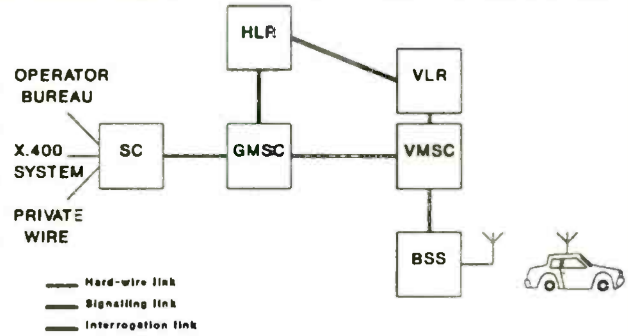
PCN, being initially a UK phenomenon, is not yet seen in quite the same way. According to Dr Queree its main attraction will be to extend mobile communications to a much wider market. PCN on 1.8GHz with its small cell size and digital technology is capable of offering specialised features not available with many of the established systems, but will require very large investment in the infrastructure of the networks, particularly if system operators each provide extensive coverage in rural areas as well as urban centres.

Mobile operation at 1.8GHz is significantly more susceptible than 900MHz to Doppler shift and the consequent multipath spreading of the received pulses.

Some bench-mark figures given at the colloquium by Philip Gaskell (Unitel) indicated that, whereas in rural areas GSM900 should be satisfactory at speeds up to about 250km/h, the equivalent speed for DCS1800 would be about 130km/h suggesting that there might, for example, be problems in using the system on high-speed trains.

In hilly terrain and urban (car) areas there should be little difference in practical performance with figures of 100km/h and 50km/h respectively for both systems. Urban (pedestrian) performance at 3km/h (GSM900) and 1.5km/h (DCS1800) were not expected to present practical problems.

Architecture for mobile terminated short-message-service providing store-and-forward transmissions of up to 83 characters on the signalling channel.



the cell, transmissions using FM.

Key factor for 40GHz MVDS and for many local telecommunications services at around 38GHz — or in the high oxygen absorption band around 60GHz (with its excellent frequency-reuse potential) — remains the development of mass-produced, low-cost millimetric-wave components. These include monolithic IC devices and use of such transmission-line structures as Finline, Microstrip and Dielectric Image Line rather than waveguides machined from solid metal.

TE O'Ciardha of (BTRL) reports the successful development of 39GHz low noise amplifiers, suitable for both RF pre-amplifiers and local-oscillator amplifiers, using GaAs millimetre-wave monolithic MMIC technology with 0.3µm-high electron mobility transistor (HEMT) devices having a yield of about 50%, 15dB gain and a noise temperature of 8.5dB.

BTRL believes that such LNAs could be mass-produced within the range of consumer budgets and represents a significant advance in demonstrating the feasibility and potential of GaAs MMICs. But BT themselves are precluded from large-scale manufacture of consumer devices and production would need to involve the semiconductor industry. At present virtually all the available low-cost millimetric-wave components come from overseas suppliers.

About 20 months ago a technical working party on millimetre-wave propagation was set up (chairman C J Gibbins, RAL) to serve as a forum for bringing together activities in industry, academia and government. Its aim was to encourage pre-competitive collaboration and co-operation between various groups, as a channel to direct technical problems from the user community to those able to provide solutions, and as a vehicle to provide guidance on direction for future work.

Still problems to be faced

Clearly, there is still considerable work needed before full use can be made of these frequencies. Though spectrum is available to carry high data rates, work at Roke Manor in conjunction with Bristol University indicates that short range millimetre e-wave channels show delay spreads of 50ns — limiting transmission rates to less than 5Msymbols/s without resort to equalisation — and that power decays more rapidly with increasing delay than at lower operating frequencies.

For hand-held transceivers, Doppler spread would seem to present problems that have not yet been fully investigated. Portsmouth Poly has been investigating indoor propagation including reflections from signals propagating through walls and floors.

Generally, the primary problem appears to remain that of cost reduction in a chicken-and-egg situation; prices won't come down until there is large-scale production and this cannot happen until there are assured markets.

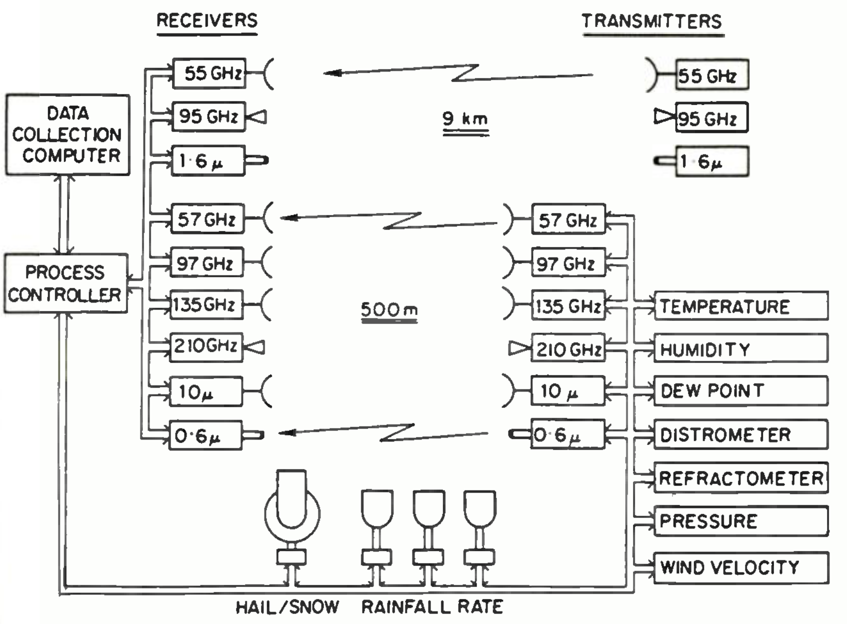
Editorial survey: use the infomation card to evaluate this article. Item P.

Working in the rain

It has become clear that work on modelling millimetre-wave propagation is rather more complex than originally anticipated. Rain attenuation, particularly from very fine droplets, is proving greater than CCIR prediction's would suggest.

Rutherford Appleton Laboratory (RAL) has established experimental terrestrial links at Chilbolton over a distance of 500m and more recently 9km. The 500m 37GHz work has been extended to 57, 97GHz and infra-red 135 and 210GHz with the 9km path currently at 55GHz, to be extended also to 95GHz.

RAL also uses its 3.075GHz dual-polarisation rain radar at Chilbolton to develop better models of rain-drop size distribution in work directed at optimising propagation predictions, including rain attenuations, at higher frequencies than have been attempted hitherto.



Block diagram of the millimetre-wave experimental system at RAL, Chilbolton.

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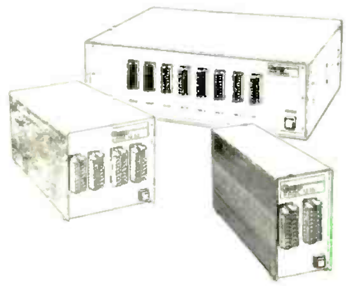

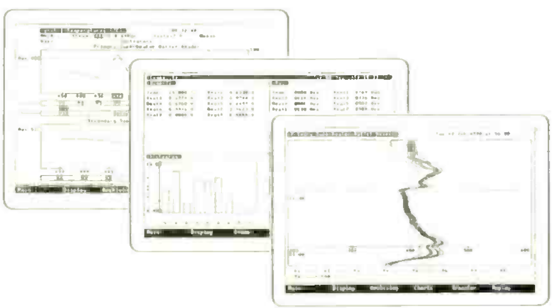

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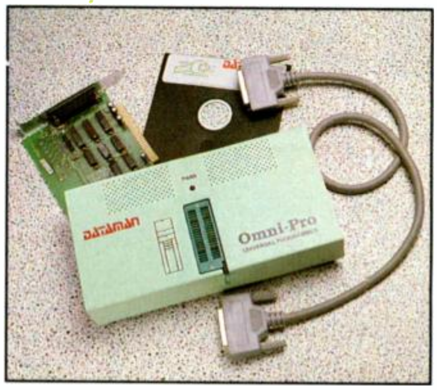

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